03.03 - 4/4/94 - 00350

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**REMEDIAL INVESTIGATION/FEASIBILITY STUDY
FIELD SAMPLING AND ANALYSIS PLAN
FOR OPERABLE UNIT NO. 8 (SITE 16)
OPERABLE UNIT NO. 11 (SITES 7 AND 80)
OPERABLE UNIT NO. 12 (SITE 3)
MARINE CORPS BASE,
CAMP LEJEUNE, NORTH CAROLINA**

CONTRACT TASK ORDER 0233

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1.0 SITE BACKGROUND

A description of the history and setting of Marine Corps Base (MCB) Camp Lejeune and the four study sites (Sites 16, 7, 80, and 3) is contained in Section 2.0 of the Remedial Investigation/Feasibility Study (RI/FS) Work Plan.

2.0 SAMPLING OBJECTIVES

The sampling and data quality objectives (DQOs) for field investigations at Sites 16, 7, 80, and 3 are summarized in Section 3.0 of the RI/FS Work Plan.

3.0 SAMPLING LOCATIONS AND FREQUENCY

This section of the Field Sampling and Analysis Plan (FSAP) describes the location and frequency of environmental samples collected during the sampling program for each of the four RI/FS sites. Support activities, sampling locations, sample matrix, and constituents to be analyzed for are discussed within this section. Detailed investigation procedures and sample handling and analytical requirements are provided in Section 5.0 and 6.0, respectively.

3.1 Operable Unit No. 8 (Site 16) - Montford Point Burn Dump

The following investigations and support activities will be conducted at Site 16:

- Surveying
- Soil Investigation
- Groundwater Investigation
- Surface Water and Sediment Investigation

Each activity and investigation is described in the following subsections.

3.1.1 Surveying

The site survey will involve the surveying of the current site features, including relationship to main roads, nearby buildings, and Northeast Creek; the cleared area; access road to the former burn dump; storm sewer line location and right-of-way; and fire break.

Prior to commencing the field sampling program, a 150 foot by 100 foot grid will be established at the site as per that shown on Figure 3-1. The elevations of these grid points will also be determined. This will allow the location of the soil sampling points to be determined in the field.

Following the completion of the field program, the location of the four test pit excavations will be surveyed. The length, elevation of both endpoints, and location of each excavation will be surveyed and plotted on a site map.

The location and elevation of a reference point on top of the PVC riser, and elevation of ground surface will be surveyed for each monitoring well. Survey points will include a latitude coordinate, a longitude coordinate, and an elevation expressed in feet of mean sea level. The vertical accuracy of the survey will be within 0.01 feet and the horizontal accuracy will be within 0.1 feet. All survey points will be correlated to the North Carolina State Plane Coordinate System.

3.1.2 Soil Investigation

A soil investigation will be conducted at Site 16 to define the shallow stratigraphy at the site and to determine the presence or absence of waste materials within the boundary of the former burn dump. Soil samples will be collected from soil borings (using split-spoon samplers) and hand auger locations in order to identify and characterize potential soil contamination.

3.1.2.1 Sampling Locations

A series of soil borings will be performed within the boundary of the former burn dump. A 150 foot by 100 foot sampling grid will be established within the former dump. A total of twenty-two (22) borings will be drilled to a depth of approximately 10 feet (or to the top of the groundwater table) to determine the shallow stratigraphy at the site and to collect samples for laboratory analysis. Two (2) soil samples from each soil boring will be submitted for chemical analysis. These samples will be collected from the surface (0 to 12 inches) and just above the groundwater table. It is estimated that the water table is within ten (10) feet of the ground surface. A mid-depth sample may be collected from these soil borings based on field observations and/or monitoring instrument readings.

Soil borings will also be performed at each of the proposed five (5) groundwater monitoring well locations. A minimum of two (2) soil samples will be collected from each of the well locations and submitted for laboratory analysis. The samples will be collected from the surface and just above the groundwater table.

Four (4) hand auger locations will be drilled and sampled southeast of the site. One location is where there is a break in the trees at the southeast corner of the former burn dump and a second location is to the southeast where there is evidence of surface drainage wash. The remaining two hand auger locations will be drilled south of the storm sewer right-of-way leading towards Northeast Creek. Two soil samples (a surficial sample and 3 to 4 feet below ground surface) will also be collected from each of these locations for laboratory analysis.

Four trenches will be excavated within the boundary of the former burn dump to investigate the existence of any remaining trash or debris. These trenches will be approximately twenty (20) feet in length and to a depth of ten (10) feet or to the top of the water table (whichever is encountered first). No soil samples are scheduled to be collected from the trenches for laboratory analyses; however, if potential contamination or elevated HNu readings are detected during the excavation of the trench, then one soil sample will be collected and submitted for analysis. The proposed location of the trenches are shown on Figure 3-2. These locations may be changed during the field program based on findings of the soil boring program.

Three additional borings will be sampled as background locations. One surficial and one subsurface (just above the water table) sample will be submitted for analysis.

The locations of the soil borings and hand augers are shown on Figure 3-1.

3.1.2.2 Analytical Requirements

All soil samples will be analyzed for full Target Compound List (TCL) organics and Target Analyte List (TAL) metals in accordance with Contract Laboratory Program (CLP) methods.

3.1.3 Groundwater Investigation

A groundwater investigation will be conducted at Site 16 to determine the presence or absence of contamination in the surficial aquifer resulting from burning and disposal activities. Four (4) shallow groundwater monitoring wells are proposed for this investigation. One well will serve as an upgradient, background well. Three shallow wells will be installed downgradient of the site to assess off-site groundwater quality. Two shallow wells will be installed within the boundary of the former burn dump. These well locations will be determined in the field based on field observations and/or HNu readings taken during the drilling of the test borings. These wells will be approximately 20 feet deep. Wells will be constructed of 2-inch I.D. PVC pipe, with 10 feet of 0.01-inch slot well screen. The proposed locations are shown on Figure 3-3.

In order to determine the rate of groundwater migration at the site, it will be necessary to obtain estimates of hydraulic conductivity of the aquifer. In situ slug tests will be conducted at three of the new well locations to evaluate horizontal hydraulic conductivity. Rising or falling head tests will be used depending on the specific location tested. Water level recovery data will be evaluated using the most appropriate analysis method for each location.

3.1.3.1 Sampling and Analysis

Two rounds of groundwater samples will be collected from the newly installed monitoring wells using bailers. The first round of samples will be collected approximately one week following the development of the wells. The second round will be collected approximately three months following the first sampling round.

Groundwater samples collected for this investigation will be analyzed for full TCL organics and TAL metals (total and dissolved) in accordance with CLP methods.

A groundwater sample will be collected from a shallow monitoring well and submitted for analysis of engineering parameters. These parameters consist of microbial count, biological oxygen demand (BOD), chemical oxygen demand (COD), ammonia nitrogen (NH_4), and alkalinity.

3.1.4 Surface Water and Sediment Investigation

A surface water and sediment investigation will be conducted at Site 16 to assess the possible impact of the former burn dump on Northeast Creek. The following provides a description of the proposed investigation.

3.1.4.1 Sampling and Analysis

Five (5) surface water and sediment sampling stations are proposed along Northeast Creek. Three of the sampling stations will be spaced approximately 400 feet along the creek south of the former burn dump. One surface water and sediment sampling station will be located one-quarter mile upstream from the burn dump and the remaining sampling location will be one-quarter mile downstream from the burn dump. One surface water and two sediment samples will be collected from each sampling station. Sediment samples will be collected from depths of 0 to 6 inches and 6 to 12 inches, and submitted for laboratory analysis. The proposed locations for the surface water and sediment sampling stations are shown on Figure 3-1.

All surface water and sediment samples will be analyzed for full TCL organics and TAL metals in accordance with CLP methods. Surface water samples will be analyzed in the field for dissolved oxygen and analyzed in the laboratory for total oxygen content (TOC). Sediment samples will also be analyzed in the laboratory for TOC and particle size distribution.

Staff gauges will be installed in Northeast Creek to assess tidal influences. A data logger and transducer will be set up and installed in Northeast Creek and also two of the installed monitoring wells to measure groundwater levels over a two to four day period to assess tidal influences.

3.2 Operable Unit No. 11 (Site 7) - Tarawa Terrace Dump

The following investigations and activities will be conducted at Site 7:

- Surveying
- Soil Investigation

Three additional borings will be sampled as background locations. One surficial and one subsurface (just above the water table) will be submitted for analysis.

Trench, soil borings, hand auger and monitoring well test boring locations are shown on Figure 3-4.

3.2.2.2 Analytical Requirements

All soil samples will be submitted for laboratory analysis of full TCL organics and TAL metals in accordance with CLP methods.

One composite soil sample will be collected from a shallow monitoring well test boring and submitted for engineering parameters analysis. This analysis will include particle-size distribution, Atterburg limits, bulk density,soil porosity, TOC, and redox potential.

3.2.3 Groundwater Investigation

A groundwater investigation will be conducted to assess the potential impact of the disposal activities on the shallow aquifer. The groundwater investigation will consist of installing two shallow groundwater monitoring wells and three temporary shallow monitoring wells. The proposed monitoring well locations are shown on Figure 3-5.

Groundwater monitoring wells will be constructed of 2-inch I.D. PVC pipe, with 10 feet of 0.01-inch slot well screen.

Information and data will be obtained from the UST investigation identified north/northwest of the Community Center. This information will be used as a comparison to groundwater analysis from newly installed wells at Site 7.

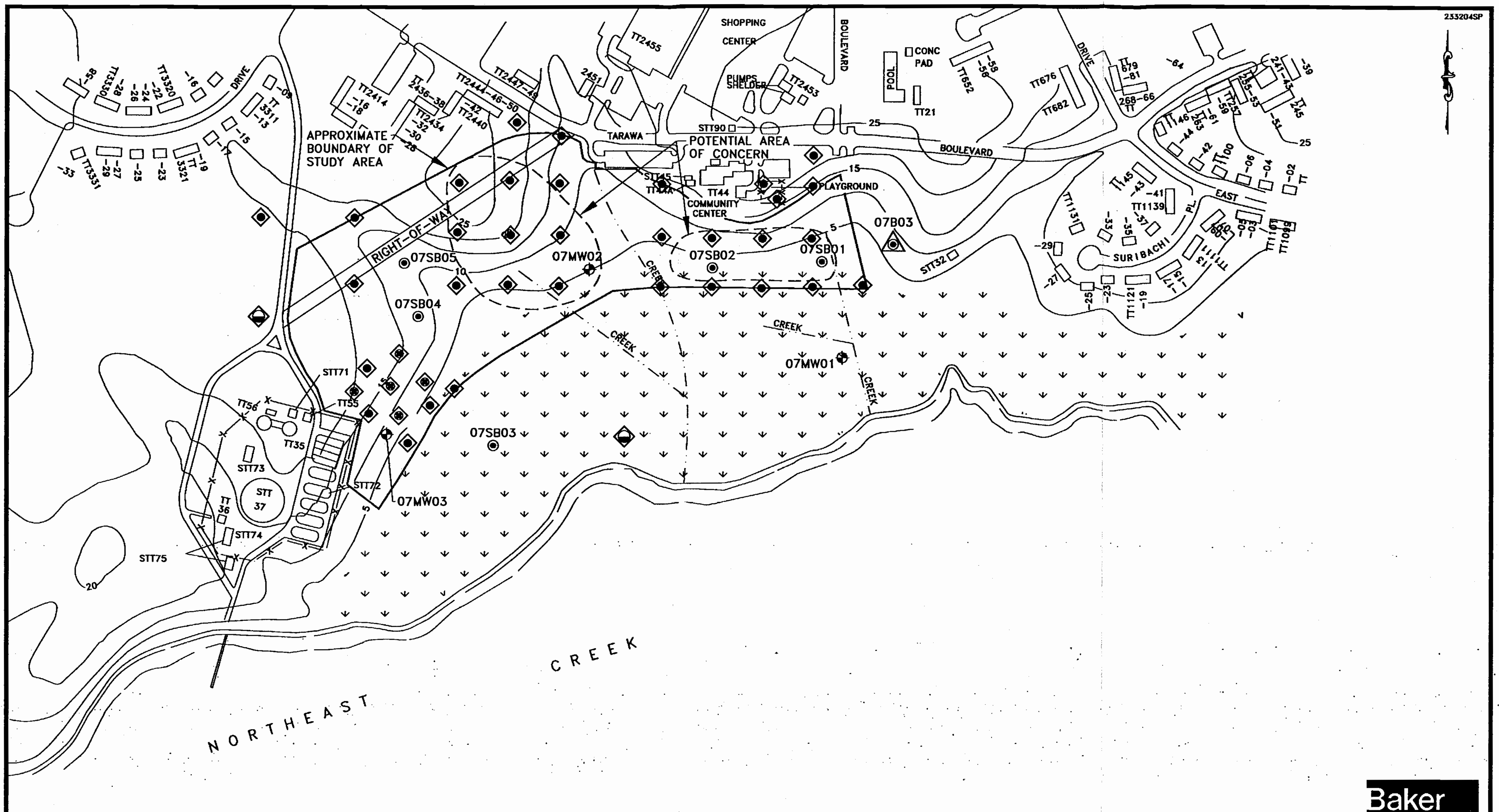
In order to determine the rate of groundwater migration at the site, it will be necessary to obtain estimates of hydraulic conductivity of the aquifer. In situ slug tests will be conducted at two existing wells and one newly installed well to evaluate horizontal hydraulic conductivity. Rising or falling head tests will be used depending on the specific location tested. Water level recovery data will be evaluated using the most appropriate analysis method for each location.

One permanent shallow monitoring well will be installed in the southern portion of the study area. The second permanent well will be installed north of the water treatment plant to assess background groundwater quality. Two temporary wells will be positioned in the southwestern portion of the study area, where access with a drill rig is restricted due to the marshy conditions. The third temporary well will be installed at a location of one of the soil borings south of the Community Center.

3.2.3.1 Sampling and Analysis

One round of groundwater samples will be collected from the three existing, two newly installed and three temporary shallow monitoring wells using bailers. The samples will be collected approximately one week following the development of the wells. A second round of groundwater samples may be collected and analyzed depending on the results of the proposed round of analyses. This additional round of analyzes would be based on contaminants of concern (COC) detected in the initial round.

All groundwater samples will be analyzed for full TCL organics and TAL metals (total and dissolved) in accordance with CLP methods.



LEGEND

07MW01	EXISTING MONITORING WELL INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
07SB01	EXISTING SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
07B03	EXISTING BACKGROUND SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
	PROPOSED SOIL SAMPLE LOCATION
	PROPOSED TRENCH
	PROPOSED SOIL BORING (MONITORING WELL TEST BORING)

SOURCE: LANTDIV, FEB. 1992

300 0 150 300 600

1 inch = 300 ft.

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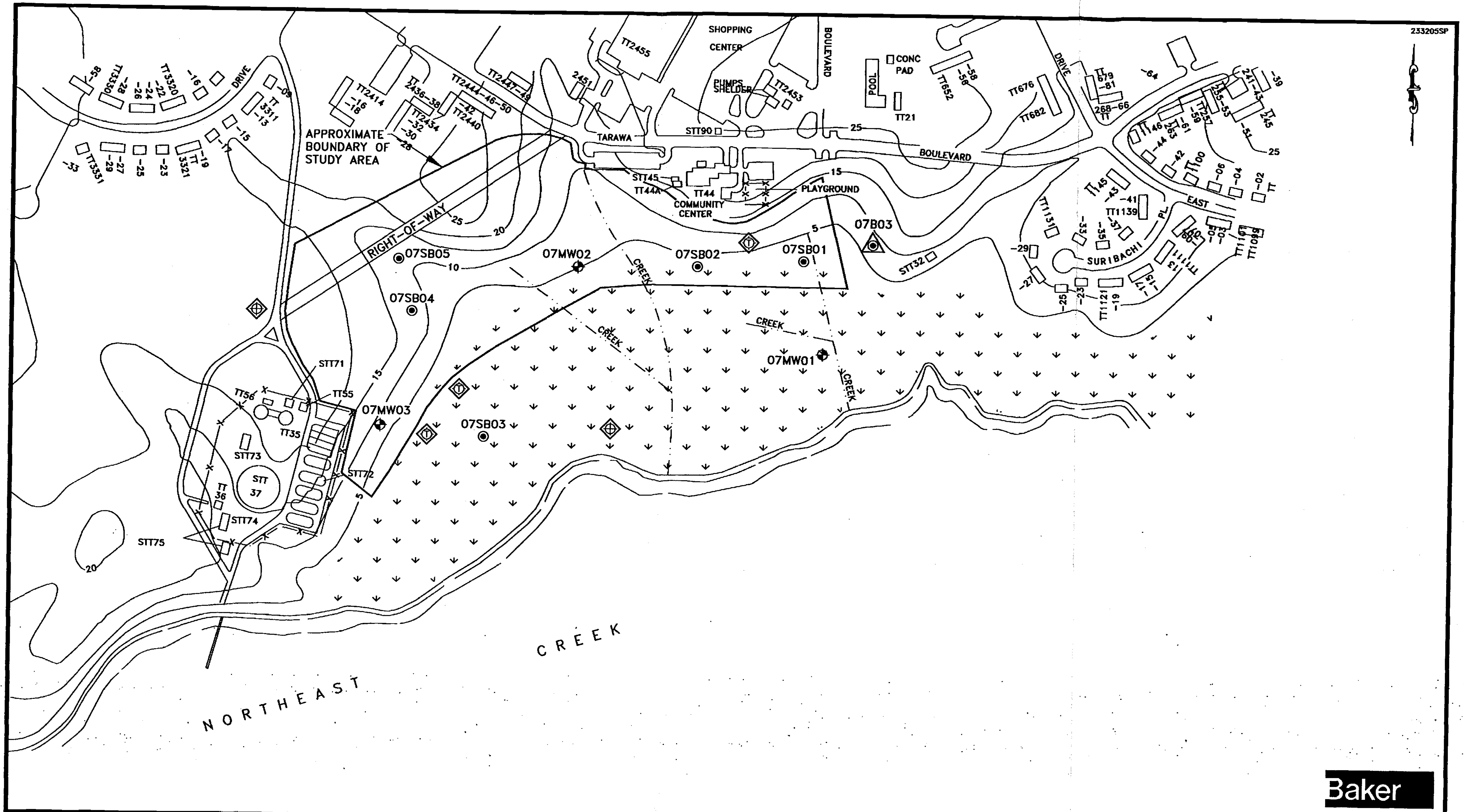
FIGURE 3-4
SOIL INVESTIGATION
SITE 7-TARAWA TERRACE DUMP
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

00350M01Z



LEGEND

07MW01 EXISTING MONITORING WELL INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

07SB01 EXISTING SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

07B03 EXISTING BACKGROUND SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

PROPOSED SHALLOW MONITORING WELL

PROPOSED TEMPORARY WELL

SOURCE: LANTDIV, FEB. 1992

300 0 150 300 600

1 inch = 300 ft.

FIGURE 3-5
GROUNDWATER INVESTIGATION
SITE 7-TARAWA TERRACE DUMP
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

00350M022

A groundwater sample will be collected from a shallow monitoring well and submitted for analysis of engineering parameters. These parameters consist of microbial count, BOD, COD, NH_4, and alkalinity.

3.2.4 Surface Water and Sediment Investigation

Potential impacts to surface water/sediment have not been assessed. There are three surface water bodies within Site 7. A surface water and sediment investigation will be conducted on each of these surface water bodies. The proposed investigation will include: Northeast Creek, the west and east tributaries of Northeast Creek, and the drainage ditch associated with the western tributary.

3.2.4.1 Sampling and Analysis

Six sampling stations are proposed for Northeast Creek. The sampling stations are spaced approximately 600 feet apart beginning upstream of the site and extending to the water treatment plant. At each sampling station, one surface water and two sediment samples, one surface sample from 0 to 6 inches and one subsurface sample from 6 to 12 inches, will be collected using stainless steel trowels, spoons, or augers.

A surface water and sediment investigation will be conducted in the western and eastern tributaries to Northeast Creek. Samples will be collected from three sampling stations in the west tributary and from two sampling stations in the east tributary. At each sampling station, one surface water and one surface sediment (0 to 6 inches) sample will be collected.

Two surface water and sediment sampling stations are proposed for the drainage ditch which feeds the western tributary to Northeast Creek. One surface water and one surface sediment (0 to 6 inches) sample will be collected at each station.

A sediment investigation will be conducted in the marsh area in the southern portion of the study area. Two sediment samples will be collected from four sampling stations. Sediment samples will be collected from the surface (0 to 6 inches) and the subsurface (6 to 12 inches) at each station.

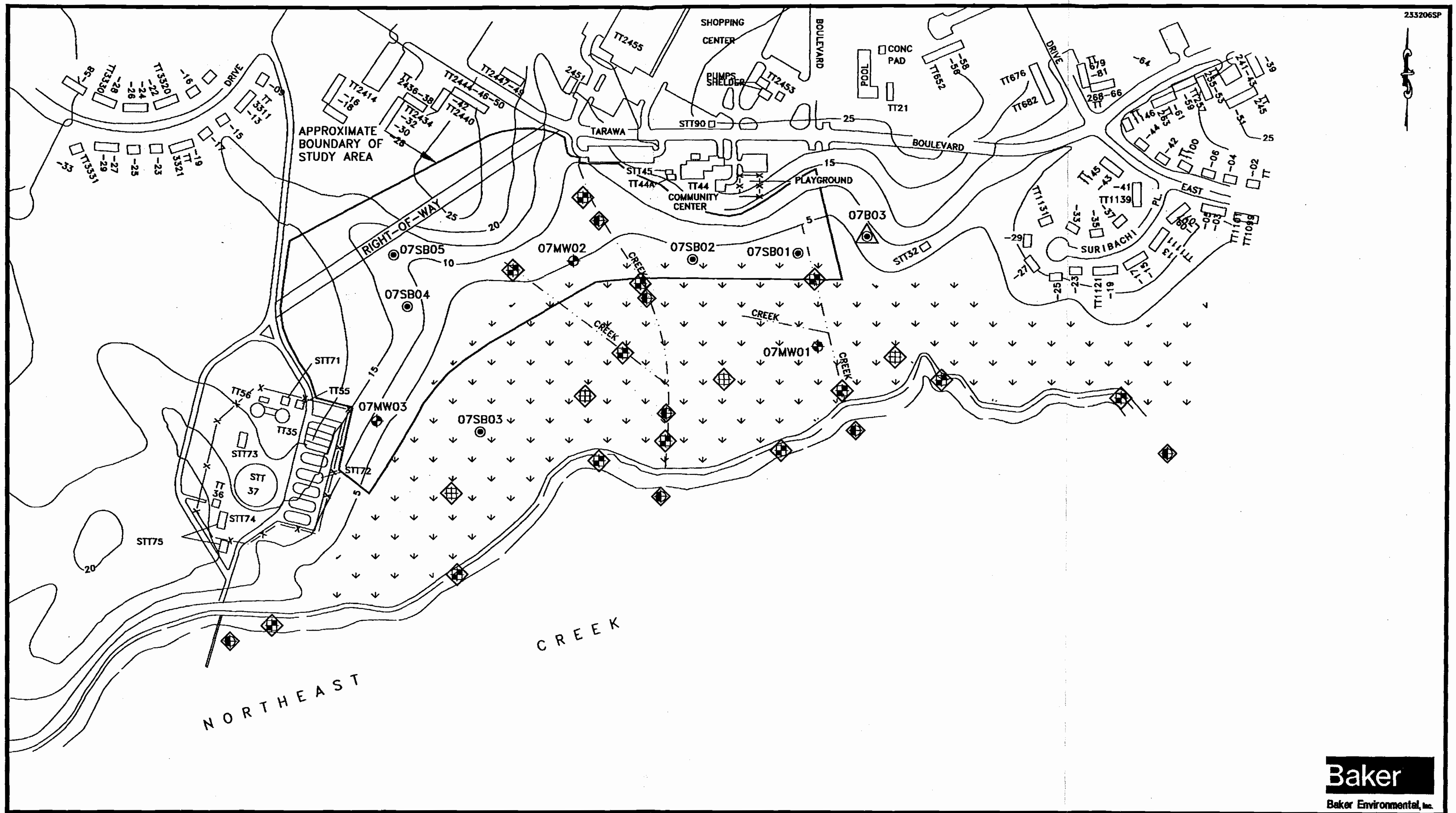
All surface water and sediment samples will be analyzed for TCL organics and TAL metals in accordance with CLP methods. Surface water samples will be analyzed in the field for dissolved oxygen and analyzed in the laboratory for TOC. Sediment samples will also be analyzed in the laboratory for TOC and particle size distribution.

In addition to the surface water and sediment investigation, benthic samples will be collected in Northeast Creek and the western tributary to Northeast Creek. Samples will be collected from three stations in the tributary and four stations in Northeast Creek.

A gill net will be positioned where the west tributary feeds Northeast Creek in order to determine whether this tributary is a significant ecological area.

Placement of staff gauges within the west and east tributaries of Northeast Creek are proposed. This will enable an assessment of possible tidal influences within the site from Northeast Creek. A data logger and transducer will be set up and installed in Northeast Creek and also in one monitoring well to measure water levels over a two to four day period to assess tidal influences.

Figure 3-6 presents the proposed sampling stations for the surface water and sediment, and benthic investigations.



LEGEND

- 07MW01 EXISTING MONITORING WELL INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
- 07SB01 EXISTING SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
- 07B03 EXISTING BACKGROUND SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991
- PROPOSED SURFACE WATER/SEDIMENT SAMPLE LOCATION
- PROPOSED SEDIMENT SAMPLE LOCATION
- PROPOSED BENTHIC SAMPLE LOCATION

SOURCE: LANTDIV, FEB. 1992

300 0 150 300 600

1 inch = 300 ft.

FIGURE 3-6
ECOLOGICAL INVESTIGATION
SITE 7-TARAWA TERRACE DUMP
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

00350M032

3.3 Operable Unit No. 11 (Site 80) - Paradise Point Golf Course Maintenance Area

The following investigations and activities will be conducted at Site 80:

- Surveying
- Soil Investigation
- Groundwater Investigation

Each activity and investigation is described in the following subsections.

3.3.1 Surveying

A site survey will be performed to establish the location and relationships of site features (such as buildings, the wash pad and sump, and the configuration of the soil mounds area), and existing groundwater monitoring wells. All existing and newly installed groundwater monitoring wells will be surveyed to establish location and elevation of a reference point on top of the PVC riser, and elevation of the ground surface. Survey points will include a latitude coordinate, a longitude coordinate, and an elevation expressed in feet of mean sea level. The vertical accuracy of the survey will be within 0.01 feet and the horizontal accuracy will be within 0.1 feet. All survey points will be correlated to the North Carolina State Plane Coordinate System.

3.3.2 Soil Investigation

The objectives of the soil investigation are to vertically and horizontally delineate potential contaminant levels in four areas of concern (lawn area around the wash pad and sump, the soil mounds located in the northeast corner of the site, the "open area" near the soil mounds, and the soil where drums where located). The activities associated with the investigation are as follows.

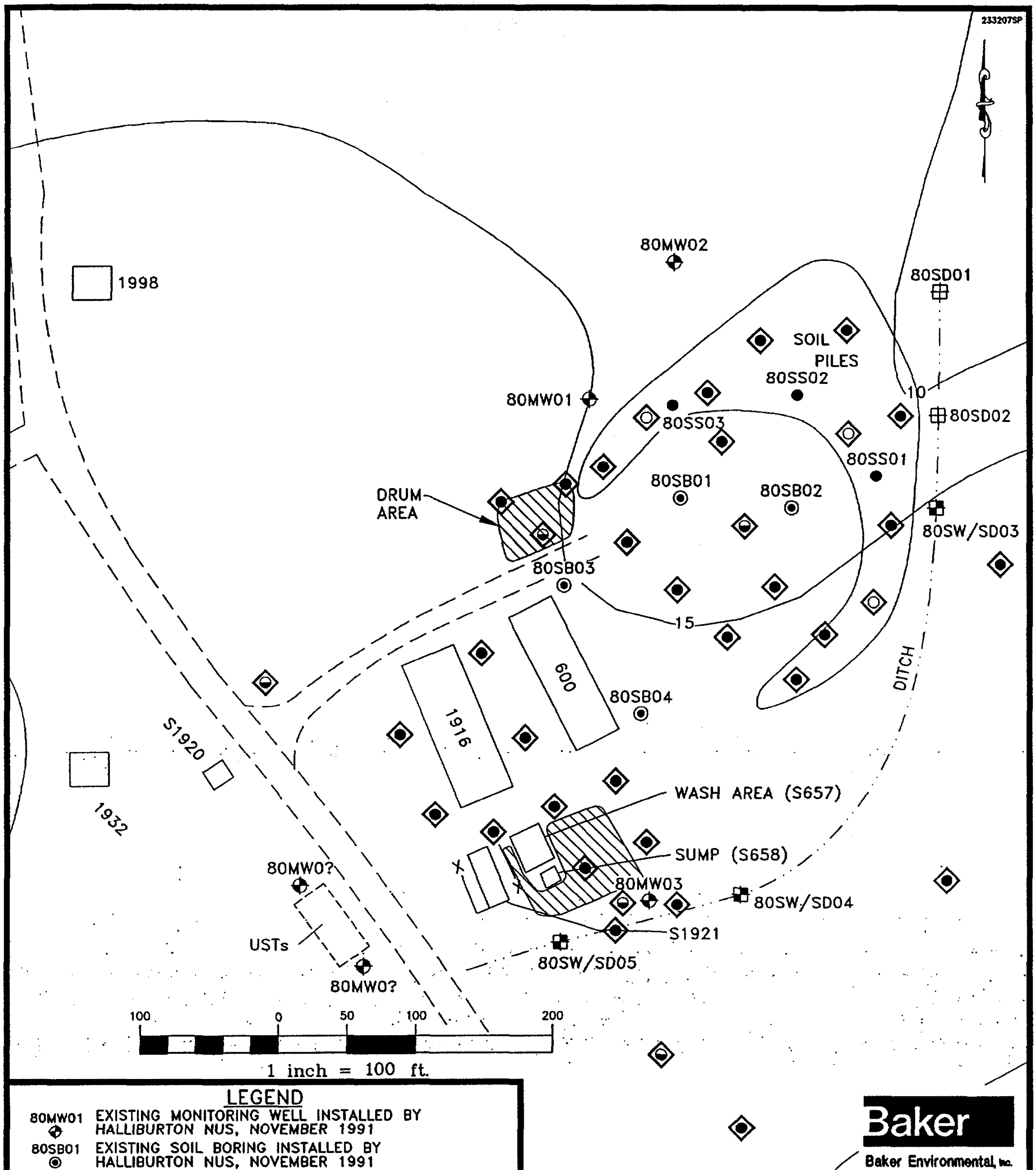
3.3.2.1 Sampling Locations

A soil investigation will be conducted in the lawn area adjacent to the collection sump and concrete wash pad. Seven test borings will be drilled with a drill rig and samples collected with a split-spoon sampler to characterize the soils in this area. One surface soil sample (depth 0 to 12 inches) and one subsurface soil sample (depth just above the groundwater table) will be collected from each location for laboratory analysis. The depth to groundwater is estimated to be between 8 and 20 feet below ground surface (bgs).

A total of four borings will be drilled and sampled between Buildings 1916 and 600, and west of Building 1916. Two soil samples will be collected from each boring (one surficial and one subsurface sample just above the water table) and submitted for analysis.

A total of seven test borings will be drilled in the "open area" adjacent to the soil mounds in the northeast corner of the study area. Test borings will be drilled using a drill rig and samples collected with a split-spoon sampler. One surface soil and one subsurface soil sample will be collected from each boring for laboratory analysis. Surface soil samples will from a depth of 0 to 12 inches. Subsurface soil samples will be collected from a depth just above the groundwater table.

A soil investigation will be conducted within the soil mounds in the northeast corner of the study area. This investigation will be conducted using hand augers. One surface soil sample will be collected from ten random areas. Surface soil samples will consist of sampling soils to a depth not to exceed 12 inches. In addition, one subsurface soil sample will be collected from three areas within the mounds. Subsurface soil samples will be collected at a depth of eight feet, which is the approximate depth of the original ground surface. Due to access restrictions, a drill rig will not be used to collect the subsurface samples. These



LEGEND

80MW01 EXISTING MONITORING WELL INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

80SB01 EXISTING SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

80SD01 EXISTING SEDIMENT SAMPLE INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

80SW/SD03 EXISTING SURFACE WATER/SEDIMENT SAMPLE INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

80SS01 EXISTING SURFACE SOIL SAMPLE INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

PROPOSED SOIL SAMPLING

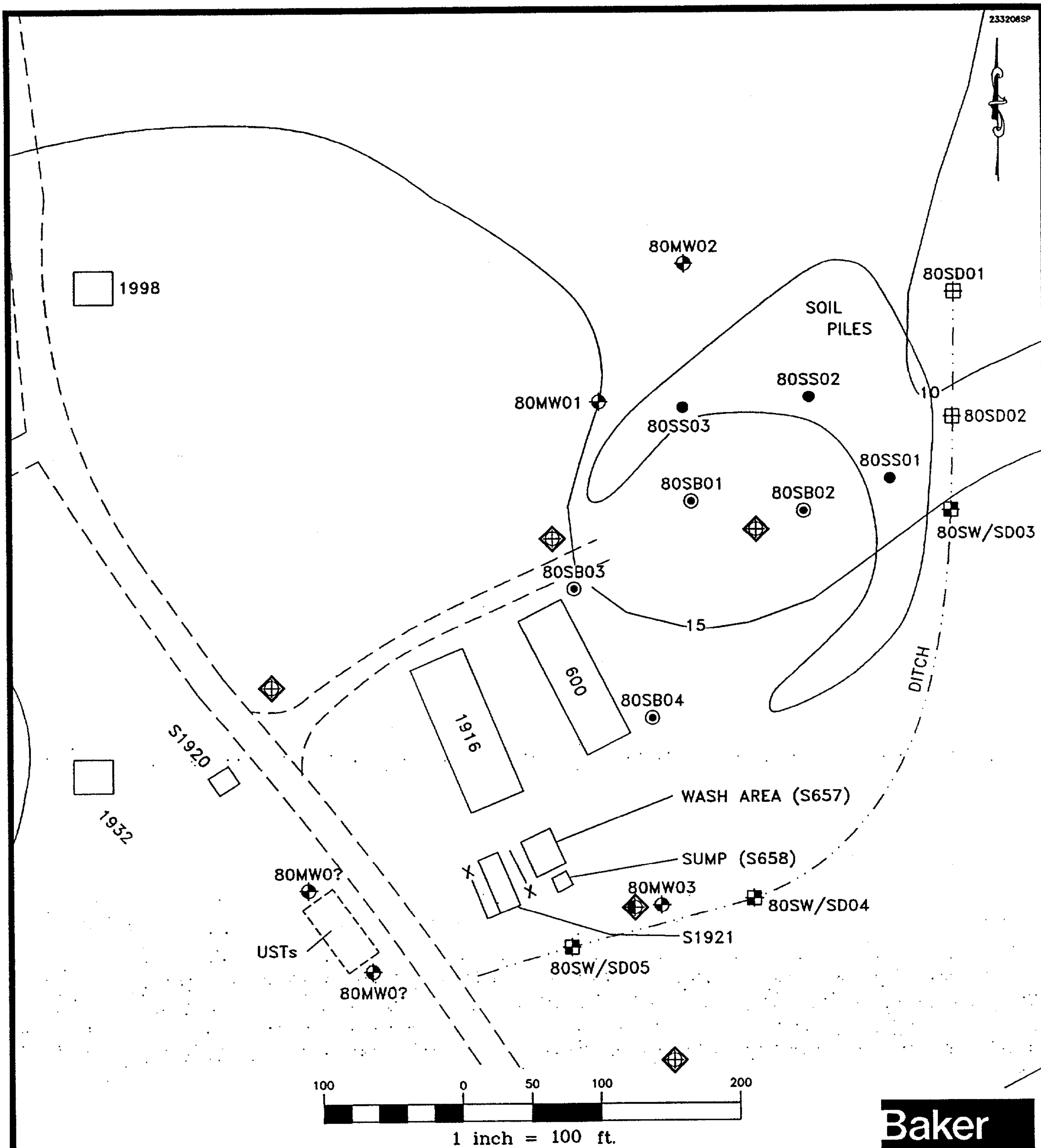
PROPOSED DEEP SOIL SAMPLING

PROPOSED SOIL BORING (MONITORING WELL TEST BORING)

AREAS OF CONCERN

SOURCE: LANTDIV, FEB. 1992

FIGURE 3-7
SOIL INVESTIGATION
SITE 80-PARADISE POINT GOLF COURSE MAINTENANCE AREA
CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



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LEGEND

80MW01 EXISTING MONITORING WELL INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

80SB01 EXISTING SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

80SD01 EXISTING SEDIMENT SAMPLE INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

80SW/SD03 EXISTING SURFACE WATER/SEDIMENT SAMPLE INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

80SS01 EXISTING SURFACE SOIL SAMPLE INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

PROPOSED SHALLOW MONITORING WELL

PROPOSED INTERMEDIATE MONITORING WELL

SOURCE: LANTDIV, FEB. 1992

FIGURE 3-8
GROUNDWATER INVESTIGATION
SITE 80-PARADISE POINT GOLF
COURSE MAINTENANCE AREA
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

3.4 Operable Unit No. 12 (Site 3) - Old Creosote Plant

The following investigations and activities will be conducted at Site 3:

- Surveying
- Soil Investigation
- Groundwater Investigation

Each activity and investigation is described in the following subsections.

3.4.1 Surveying

A site survey will be performed to establish the location and relationships of site features (such as concrete pads and the chimney), and existing groundwater monitoring wells. A 200 foot by 200 foot sampling grid will be established in the northern portion of the study area. In the southern portion of the study area, a 50 foot by 50 foot sampling grid will be established around the former creosote treatment area. All existing and newly installed groundwater monitoring wells will be surveyed to establish location and elevation of a reference point on top of the PVC riser, and the elevation of the ground surface. Survey points will include a latitude coordinate, a longitude coordinate, and an elevation expressed in feet of mean sea level. The vertical accuracy of the survey will be within 0.01 feet and the horizontal accuracy will be within 0.1 feet. All survey points will be correlated to the North Carolina State Point Coordinate System.

3.4.2 Soil Investigation

The activities associated with the soil investigation are as follows.

3.4.2.1 Sampling Locations

In the northern portion of the study area, surface soil samples (0 to 12 inches) will be collected from the nine points on the established sampling grid and from the four centers of the grid quadrants. Soil samples will be collected using hand augers.

The soil investigation in the southern portion of the study area will consist of a total of 36 sampling points. These sampling points are distributed on the established sampling grid, around the two concrete pads, and along the estimated alignment of the railroad spur to the treatment area. All soil samples from the southern portion of the study area will be collected using hand augers from a depth of 0 to 12 inches.

ENSYS sampling locations that detect PAHs and/or creosote will be expanded north, east, south, and west of the original sampling point to delineate the extent of potential contaminants. The sampling point will be extended 10 feet in the four directions and analyzed. If potential contaminants are detected at the new locations, sampling will be extended another 10 feet. When an extended sampling point is "nondetect," sampling will be moved back 5 feet and analysis performed. No further sampling and analysis will be done after this point.

In areas delineated as containing potential contaminants, a soil boring will be performed with samples collected at the surface, just above the water table and at the mid-depth, and submitted for laboratory analysis.

Soil samples will be collected during the drilling of monitoring well borings. A maximum of three soil samples will be submitted per test boring. These samples will include a surficial soil (0 to 12 inch depth) and two subsurface soil samples, one from just above the water table and one at mid-depth.

Three additional borings will be sampled as background locations. One surficial and one subsurface (just above the water table) will be submitted for analysis.

Figures 3-9 and 3-10 present the locations of the proposed soil sampling points in the northern and southern portions of the study area, respectively. Figure 3-11 presents the location of the proposed monitoring wells.

3.4.2.2 Analytical Requirements

All surface soil samples from both the northern and southern portions of the study area will be analyzed in the field using ENSYS PAH Soil Sensitivity and ENSYS Petro Soil test kits to detect PAHs and total creosote, respectively. Sample locations where levels of PAHs and/or creosote are above detection limits for the ENSYS test kits will be expanded to determine the horizontal extent of the constituents. Based on the quantitative findings of these immunoassay-based testing methods, positive results for total PAHs and/or total creosote will be submitted for confirmatory laboratory analysis. In addition, ten percent of soil samples reported as nondetect will be submitted for laboratory analysis.

Soil samples collected from the shallow monitoring well locations will be submitted for analysis of TCL semivolatile organics. The soil samples collected from the intermediate monitoring well test boring will be analyzed for full TCL organics and TAL metals in accordance with CLP methods.

One composite soil sample will be collected from a shallow monitoring well test boring and submitted for engineering parameters analysis. This analysis will include particle-size distribution, Atterburg limits, bulk density, soil porosity, TOC, and redox potential.

3.4.3 Groundwater Investigation

The groundwater investigation will consist of the installation of four shallow monitoring wells (estimated depth of 20 feet) and one intermediate depth monitoring well (40 to 50 feet), adjacent to existing shallow monitoring well 03MW02. The locations of the proposed groundwater monitoring wells are presented on Figure 3-11.

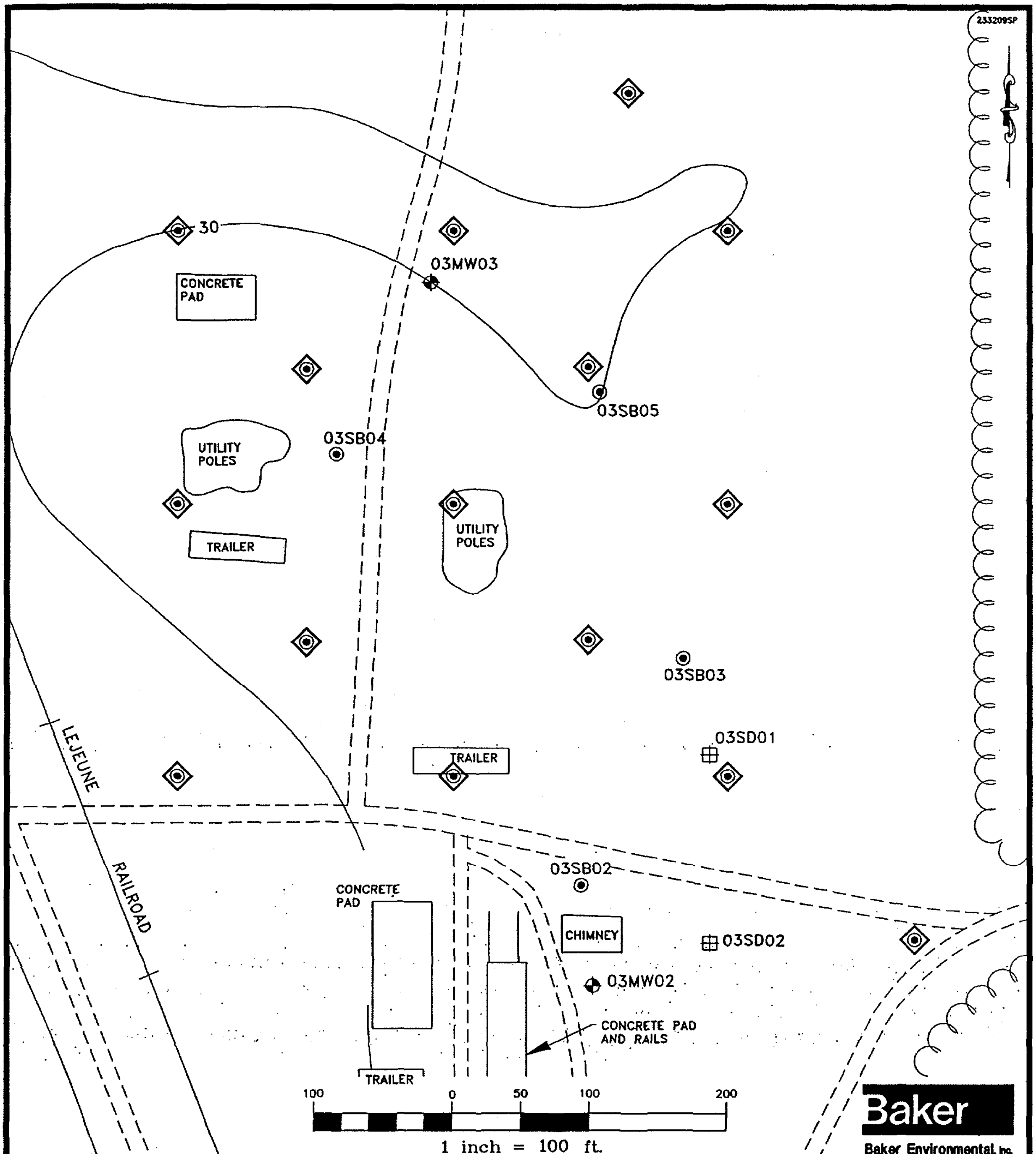
Groundwater monitoring wells will be constructed of 2-inch I.D. PVC pipe, with 10 feet of 0.01-inch slot well screen.

In order to determine the rate of groundwater migration at the site, it will be necessary to obtain estimates of hydraulic conductivity of the aquifers. In situ slug tests will be conducted at three newly installed shallow monitoring wells and the newly installed intermediate well to evaluate horizontal hydraulic conductivity. Rising or falling head tests will be used depending on the specific location tested. Water level recovery data will be evaluated using the most appropriate analysis method for each location.

3.4.3.1 Sampling and Analysis

One round of groundwater samples will be collected from 3 existing and 4 newly installed shallow monitoring wells, and one newly installed intermediate well using bailers. The samples will be collected approximately one week following the development of the wells. All shallow groundwater samples will be analyzed for TCL semivolatile organics in accordance with CLP methods. The groundwater sample collected from the intermediate well will be analyzed for full TCL organics and TAL metals (total and dissolved) in accordance with CLP methods.

A groundwater sample will be collected from a shallow monitoring well and submitted for analysis of engineering parameters. These parameters consist of microbial count, BOD, COD, NH_4, and alkalinity.



LEGEND

03MW01 — MONITORING WELL INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

03SB01 — SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

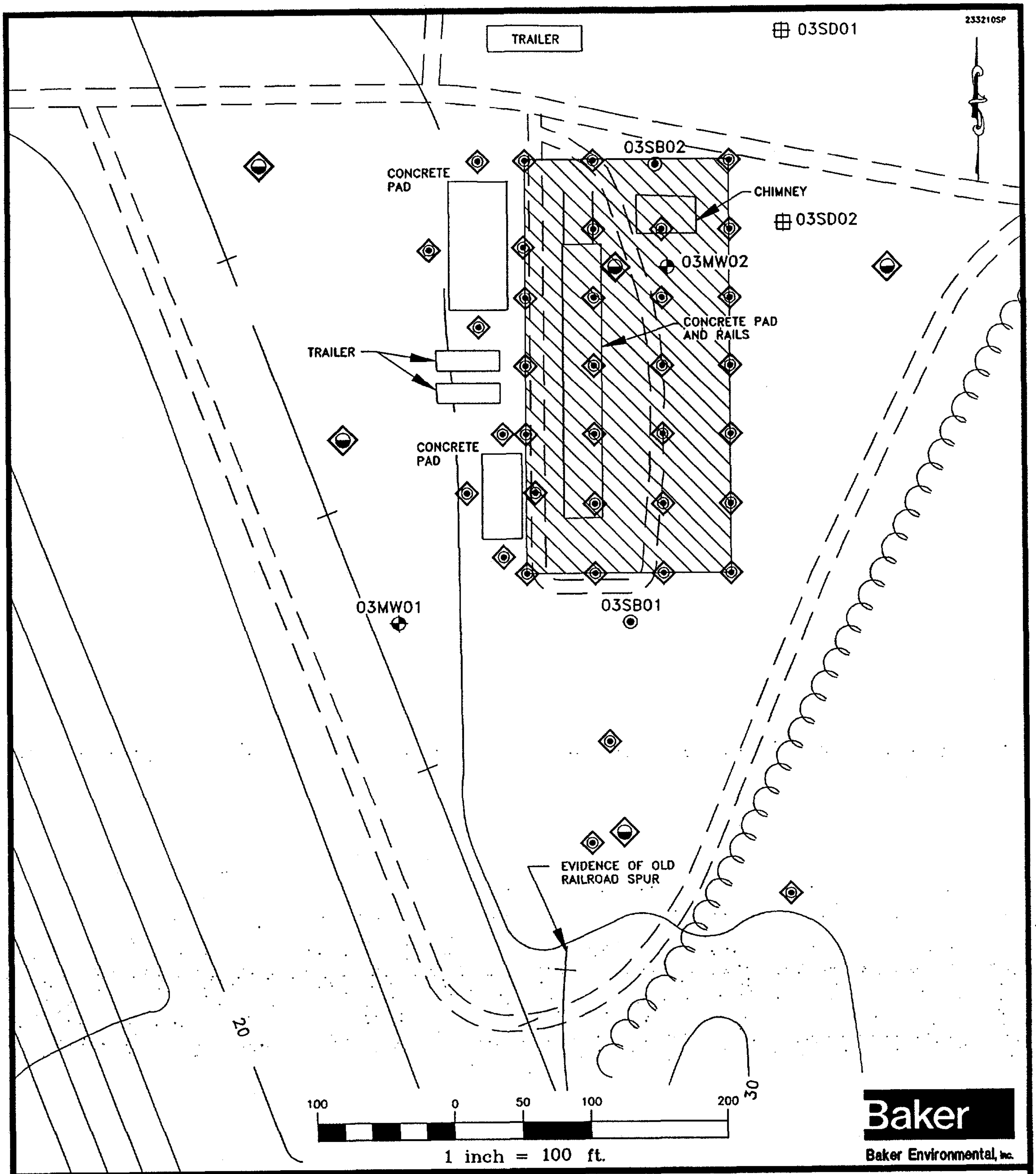
03SD01 — SEDIMENT SAMPLE LOCATION INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

PROPOSED ENSYS TESTING

SOURCE: LANTDIV, FEB. 1992

FIGURE 3-9
SOIL INVESTIGATION
NORTH AREA - SITE 3
OLD CREOSOTE PLANT
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

03MW01 MONITORING WELL INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

03SB01 SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

03SD01 SEDIMENT SAMPLE LOCATION INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

PROPOSED ENSYS TESTING

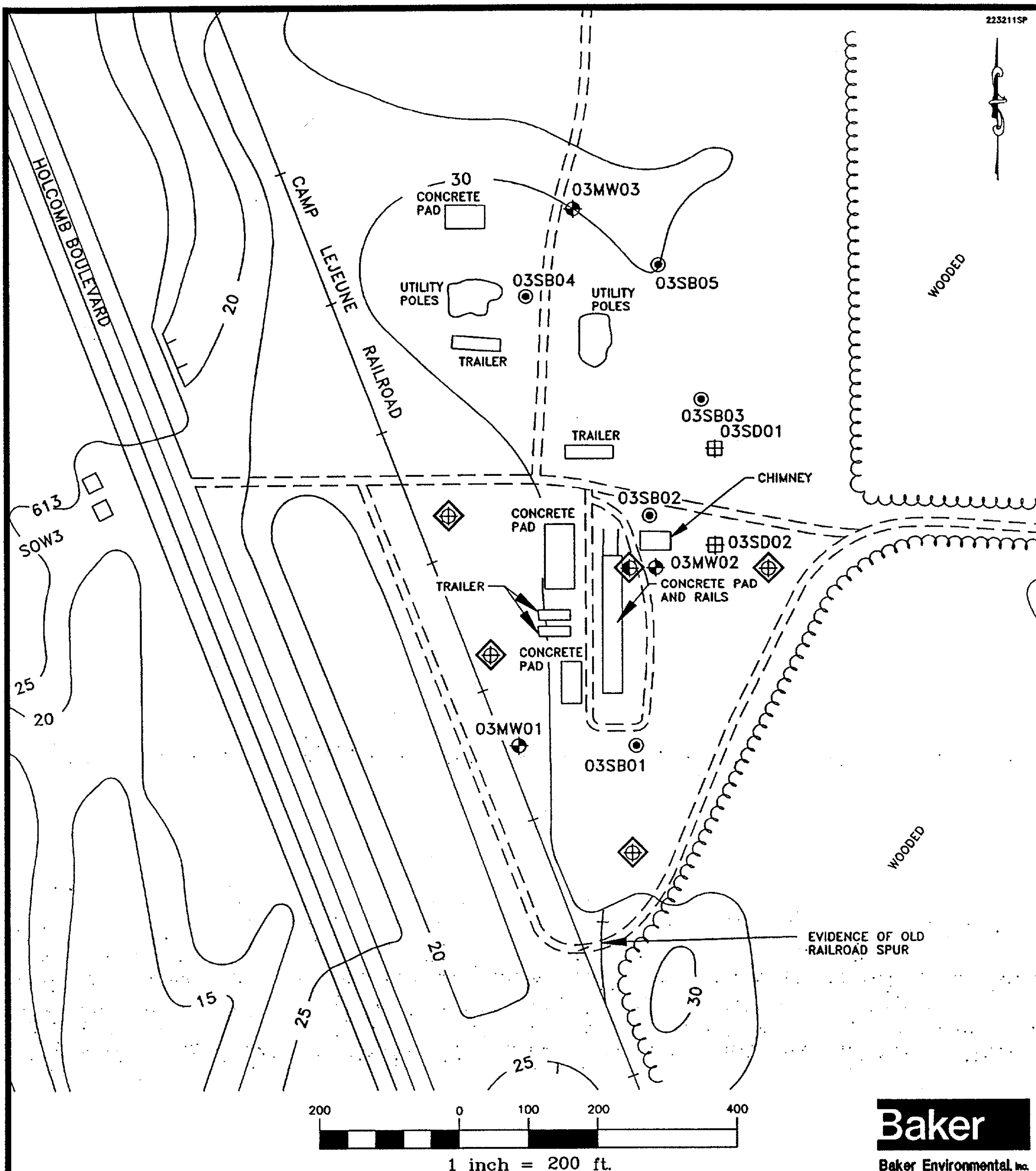
PROPOSED SOIL BORING (MONITORING WELL TEST BORING)

AREA OF CONCERN

SOURCE: LANTDIV, FEB. 1992

FIGURE 3-10
SOIL INVESTIGATION
SOUTH AREA - SITE 3
OLD CREOSOTE PLANT
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND

03MW01 MONITORING WELL INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

03SB01 SOIL BORING INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

03SD01 SEDIMENT SAMPLE LOCATION INSTALLED BY HALLIBURTON NUS, NOVEMBER 1991

PROPOSED SHALLOW MONITORING WELL

PROPOSED INTERMEDIATE MONITORING WELL

SOURCE: LANTDIV, FEB. 1992

FIGURE 3-11
GROUNDWATER INVESTIGATION
SITE 3-OLD CREOSOTE PLLANT
CTO-0233

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

3.5 QA/QC Samples

QA/QC requirements for this investigation are presented in the Quality Assurance Project Plan (QAPP) which is provided as Section II of this FSAP. The following QA/QC samples will be collected at each of the four sites during field sampling activities:

- Trip Blanks

  Trip blanks are defined as samples which originate from the analyte-free water taken from the laboratory to the sampling site and returned to the laboratory with the volatile organic analysis (VOA) samples. One trip blank should accompany each cooler containing samples for volatile organic analysis. The blanks should only be analyzed for volatile organics.

- Equipment Rinsates

  Equipment rinsates are the final analyte-free water rinse from equipment decontamination procedures. Equipment rinsates will be collected daily during each sampling event. Initially, samples from every other day should be analyzed. If analytes pertinent to the project are found in the rinsates, the remaining samples must be analyzed. The results from the rinsates will be used to evaluate the decontamination methods. This comparison is made during data validation and the rinsates are analyzed for the same parameters as the related samples.

  One equipment rinsate will be collected per day of field sampling.

- Field Blanks

  Field blanks consist of the source water used in equipment decontamination procedures. At a minimum, one field blank for each source of water must be collected and analyzed for the same parameters as the related samples.

  Two field blanks (ambient condition blanks) will be prepared at the commencement of each sampling event. The field blanks will be prepared by pouring potable water (used for decontamination purposes) into one set of sample bottles and deionized water directly into an additional set of sample bottles.

- Field Duplicates

  Field duplicates for soil samples are collected, homogenized, and split. All samples except VOAs are homogenized and split. Volatiles are not mixed, but select segments of soil are taken from the length of the core and placed in 4-ounce glass jars. The duplicates for water samples should be collected simultaneously. The water samples will not be composited.

  Field duplicates will be collected at a frequency of 10 percent.

- Matrix Spike/Matrix Spike Duplicates (MS/MSD)

  MS/MSD samples are collected to evaluate the matrix effect of the sample upon the analytical methodology. A matrix spike and matrix spike duplicate must be performed for each group of samples of a similar matrix

  MS/MSD samples will be collected at a frequency of 5 percent.

3.6 Investigative Derived Waste

3.6.1 Groundwater Characterization

One sample from each site tanker of development and purge water will be collected and submitted for analysis. Analysis will consist of TCL organics and TAL metals (total and dissolved) in accordance with CLP methods.

4.0 SAMPLE DESIGNATION

In order to identify and accurately track the various samples, all samples collected during this investigation, including QA/QC samples, will be designated with a unique number. The number will serve to identify the investigation, the site, the area within the site, the sample media, sampling location, the depth (soil) or round (groundwater) of sample, and QA/QC qualifiers.

The sample designation format is as follows:

Site#-Location-Media/Station# or QA/QC-Depth/Round

An explanation of each of these identifiers is given below.

Site#	This investigation includes Sites 16, 7, 80, and 3.
Location	The location designation will refer to a surface feature (e.g., LA = Lawn Area) or grid (e.g., NA = Northern Area).
Media	SB = Soil Boring (soil sample from a boring) GW = Groundwater SW = Surface Water SD = Sediment TP = Test Pit
Station#	Each soil test boring or monitoring well will be identified with a unique identification number.
QA/QC	(FB) = Field Blank (D) = Duplicate Sample (following depth/round) (TB) = Trip Blank (ER) = Equipment Rinsate
Depth/Round	Depth indicators will be used for soil samples. The number will refer to the depth of the top of the sampled interval. For example: 00 = top of sample at ground surface 01 = top of sample is 1 foot below ground surface 02 = top of sample is 3 feet below ground surface 03 = top of sample is 5 feet below ground surface Round indicator will be used for groundwater samples (round one and round two). For example:

Under this sample designation format the sample number 80-GW03DW-01D refers to:

<u>80</u>-GW03DW-01D	Site 80
80-<u>GW</u>03DW-01D	Groundwater sample
80-GW<u>03</u>DW-01D	Monitoring well #3
80-GW03<u>DW</u>-01D	Deep well

80-GW03DW-01D	Round 1
80-GW03DW-01D	Duplicate (QA/QC) sample

The sample designation 3-NA-SB11-00D refers to:

3-NA-SB11-00D	Site 3
3-NA-SB11-00D	Northern Area
3-NA-SB11-00D	Soil Boring
3-NA-SB11-00D	Test boring #11
3-NA-SB11-00D	Sample depth interval 0 to 12"
3-NA-SB11-00D	Duplicate (QA/QC) sample

This sample designation format will be followed throughout the project. Required deviations to this format in response to field conditions will be documented.

5.0 INVESTIGATIVE PROCEDURES

The investigative procedures to be used for Sites 16, 7, 80, and 3 will be discussed in the following subsections. These procedures include soil sample collection, monitoring well installation (both shallow and intermediate), in situ slug tests, groundwater sample collection, surface water sample collection, sediment sample collection, decontamination procedures, surveying, handling of site investigation derived wastes, and water level measurements. Note that all of these procedures will follow the field methods described in the USEPA, Region IV, Environmental Services Division (ESD), Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual (ECBSOPQAM), February 1, 1991. Additional guidance from other sources such as ASTM may be used, but if the ASTM and ESD methods are in conflict, the ESD procedure will be used.

5.1 Soil Sample Collection

Surface and subsurface soil samples will be collected throughout Sites 16, 7, 80 and 3. Soil samples will be collected from borings advanced by a drilling rig and during the installation of monitoring wells. Soil samples will also be collected from borings advanced by hand auger. Some soil samples will be collected from test pits (task at Sites 16 and 7) excavated by a backhoe. All ground penetrations will receive utility clearance from the appropriate on-base personnel. Appendix A contains Baker's standard operating procedures (SOPs) for soil sample acquisition.

5.1.1 Soil Borings Advanced by Hand Auger (Task at Sites 16, 7, 80 and 3)

Hand augering is the most common manual method used to collect subsurface samples. Four inch diameter augers with cutting heads are pushed and twisted into the ground and removed as the buckets are filled. The auger holes are advanced one bucket at a time. The practical depth of investigation using a hand auger is related to the material being sampled. During this investigation, hand augers will be used to collect discrete grab samples of soil from the 0 to 12-inch, and just above the water table.

When a vertical sampling interval has been established, one auger bucket is used to advance the auger hole to the first desired sampling depth. Since discrete grab samples are to be collected to characterize each depth, a new bucket will be placed on the end of the auger extension immediately prior to collecting the next sample. The top several inches of soil should be removed from the bucket to minimize the chances of cross-contamination of the sample from fall-in of material from the upper portions of the hole. The bucket auger will be decontaminated between samples as outlined in Section 5.8.

5.1.2 Soil Borings and Monitoring Well Boreholes (Task at Sites 16, 7, 80 and 3)

Soil samples from soil borings advanced by a drilling rig will be collected using a split-spoon sampler. A split-spoon sampler is a steel tube, split in half lengthwise, with the halves held together by threaded collars at either end of the tube. This device can be driven into unconsolidated materials using a drive weight connected to the drilling rig. A split-spoon sampler (used for performing Standard Penetration Tests) is two inches outer diameter (OD) and 1-3/8-inches inner diameter (I.D.). This standard spoon is available in two common lengths providing either 20-inch or 26-inch internal longitudinal clearance for obtaining 18-inch or 24-inch long samples, respectively. Split-spoons capable of obtaining 24-inch long samples will be utilized during this investigation.

Split-spoon samples will be collected continuously from the ground surface to the ground water table in each soil boring. Soil borings that will be converted into shallow monitoring wells (monitoring well boreholes) will be advanced approximately 12 feet below the water table. Soil borings converted into intermediate monitoring wells at Sites 80 and 3 will be advanced to a depth of approximately 40 to 50 feet bgs, based on encountering the upper unit of the Castle Hayne Formation. The physical characteristics of the samples will be described by the site geologist. The soil in the sampler will be classified according to the Unified Soil Classification System (USCS). Soil sample descriptions will be recorded in the field geologist's notebook.

Selected split-spoon samples will be submitted to the laboratory for analysis. Soil samples will be collected in 2-foot increments to the top of the water table. Surface soil samples will not be collected using a split-spoon sampler because a sufficient quantity of sample cannot be retained from 0 to 12 inches using this sampling device. Hence, surface samples will be collected using a stainless-steel spoon, hand auger, or by advancing the augers and retaining the cuttings. For borings only, split-spoon samples will be collected from approximately one foot to the top of the water table; for borings advanced for monitoring well installation, split spoon samples will be collected continuously from ground surface to the top of the water table. Below the water table, soil samples will be collected at 5-foot intervals.

The following procedures for collecting soil samples in split-spoons will be used:

1. The surface sample will be collected by driving the split-spoon with blows from a 140-pound hammer falling 30 inches in accordance with SOP Soil and Rock Sample Acquisition.

2. Advance the borehole to the desired depth using hollow stem auger drilling techniques. The split-spoon will be lowered into the borehole inside the hollow stem auger (this will ensure that undisturbed material will be sampled).

3. Drive the split-spoon using procedures outlined in 1 above.

4. Repeat this operation until the borehole has been advanced to the selected depth. Split-spoon samples will be collected continuously until groundwater is encountered.

5. Record in the field logbook the number of blows required to effect each six inches of penetration or fraction thereof. The first six inches is considered to be a seating drive. The sum of the number of blows required for the second and third six inches of penetration is termed the penetration resistance, N. If the sampler is driven less than 18 inches, the penetration resistance is that for the last one foot of penetration. (If less than one foot is penetrated, the logs shall state the number of blows and the fraction of one foot penetrated.) In cases where samples are driven 24 inches, the sum of second and third 6-inch increments will be used to calculate the penetration resistance. (Refusal of the SPT will be noted as 50 blows over an interval equal to or less than 6-inches; the interval driven will be noted with the blow count.)

6. Bring the sampler to the surface and remove both ends and one half of the split-spoon such that the soil recovered rests in the remaining half of the barrel. Describe the recovery (length), composition, structure, consistency, color, condition, etc., of the recovered soil; then put into sample jars.

7. Split-spoon samplers shall be decontaminated after each use and prior to the initial use at a site according to procedures outlined in Section 5.6.

The following procedures are to be used for soil samples submitted to the laboratory:

1. After sample collection, remove the soil from the split-spoon sampler. Prior to filling laboratory containers, the soil sample should be mixed, in an aluminum tray with stainless steel spoons, as thoroughly as possible to ensure that the sample is as representative as possible of the sample interval. Soil samples for volatile organic compounds should <u>not</u> be mixed. Discrete soil samples from different sections of the split-spoon, representative of the soil types encountered, will be placed in the sample jar with a minimum of disturbance. Further, sample containers for volatile organic compounds analyses should be filled completely without head space remaining in the container to minimize volatilization.

2. Record all pertinent sampling information such as soil description, sample depth, sample number, sample location, and time of sample collection in the field logbook. In addition, label, tag, and number the sample bottle(s) as outlined in Section 6.0.

3. Pack the samples for shipping. Attach seal to the shipping package. Chain-of-Custody Forms and Sample Request Forms will be properly filled out and enclosed or attached (Section 6.0).

4. Decontaminate the split-spoon sample as described in Section 5.6. Replace disposable latex gloves between sample stations to prevent cross-contamination of samples.

5.1.3 Test Pits (Task at Sites 16 and 7)

Test pits will be excavated using a backhoe. The following procedures apply to the excavation and backfilling of a typical test pit.

- The positions of the test pits shall be located in the field by the Field Team Leader or Site Manager. Utility clearance shall be obtained from Activity personnel for all test pit locations prior to excavation.

- Excavation equipment shall be thoroughly decontaminated prior to and after each test pit excavation.

- A safety zone shall be established around the test pit location prior to initiation of excavation.

- Excavation shall commence by removing lifts of no more than approximately 6 to 12-inches of soil.

- Test pit excavation will continue to a depth of 10 feet or to the water table (whichever is encountered first).

- Soil samples may be collected during the excavation. The collected sample shall consist of visually contaminated soil or soils exhibiting elevated levels of organics from monitoring instrument readings encountered during excavation. If no suspected contaminated soil is encountered, then a sample shall not be collected. Samples will be collected from the backhoe bucket using a stainless steel trowel or spoon. Samples from the backhoe bucket will be collected from the center portion of the bucket to avoid contact. These samples will be logged, packaged, and submitted to the laboratory for analysis.

- The field inspector shall log the test pit soils and record observations and the test pit cross-section shall be sketched in the Field Logbook with notable features identified.

- Test pit depths (and water levels) may be measured using an engineers rule (six foot) or a weighted measuring tape. Depths shall be measured from the ground surface.

- Upon completion, test pits shall be immediately backfilled.

- Test pit locations shall be marked with five wooden stakes; one at each corner and one in the center. The test pit number shall be recorded on the centrally located stake.

Backfilling of trenches and test pits is a normally accepted practice to reduce immediate site hazards and minimize the potential for rainwater accumulation and subsequent contaminant migration.

After inspection and completion of the appropriate test pit logs, backfill material should be returned to the pit under the direction of the field inspector. The test pit cover should be inspected and further regraded, if necessary. Where it is safe to do so, the backhoe bucket should be used to compact each one to 2-foot layer of clean backfill as it is placed, to reduce settling and compaction. Appendix B contains the SOPs for Test Pit and Trench Excavations.

5.2 Monitoring Well Installation (Task at Sites 16, 7, 80 and 3)

Shallow monitoring wells will be installed to monitor the shallow (water table) water-bearing zone. It is estimated that these wells will be installed from 15 to 30 feet. Procedures for the installation and construction of shallow monitoring wells are presented below (see Figure 5-1):

- Activity personnel will approve all monitoring well locations. These locations shall be free of underground or overhead utility lines.

- A borehole will be advanced by a drilling rig using hollow stem augers. Initially, the boreholes will be advanced with 3-1/4-inch I.D. augers. After the borehole has been advanced to its final depth, the borehole will be overdrilled with 6-1/4-inch I.D. augers (for well installation only).

- Soil (split spoon) samples will be collected continuously during borehole advancement. Samples will be collected according to the procedures outlined in Section 5.1.2.

- Upon completion of the borehole to the desired depth, monitoring well construction materials will be installed (inside the hollow stem augers).

- PVC is the material selected for monitoring well construction. It was selected on the basis of its low cost, ease of use and flexibility. USEPA Region IV requires justification of using PVC.

- Ten feet of 2-inch I.D., Schedule 40, #10 slot (0.010 inch) screen with a bottom cap will be installed. The screen will be connected to threaded, flush-joint, PVC riser. The riser will extend 2 to 3 feet above the surface. A PVC slip-cap vented to the atmosphere, will be placed at the top of the riser.

- The annular space around the screen will be backfilled with a well-graded medium to coarse sand (No. 1 or No. 2 Silica Sand) as the hollow-stem augers are being withdrawn from the borehole. Sand shall be placed from the bottom of the boring to approximately

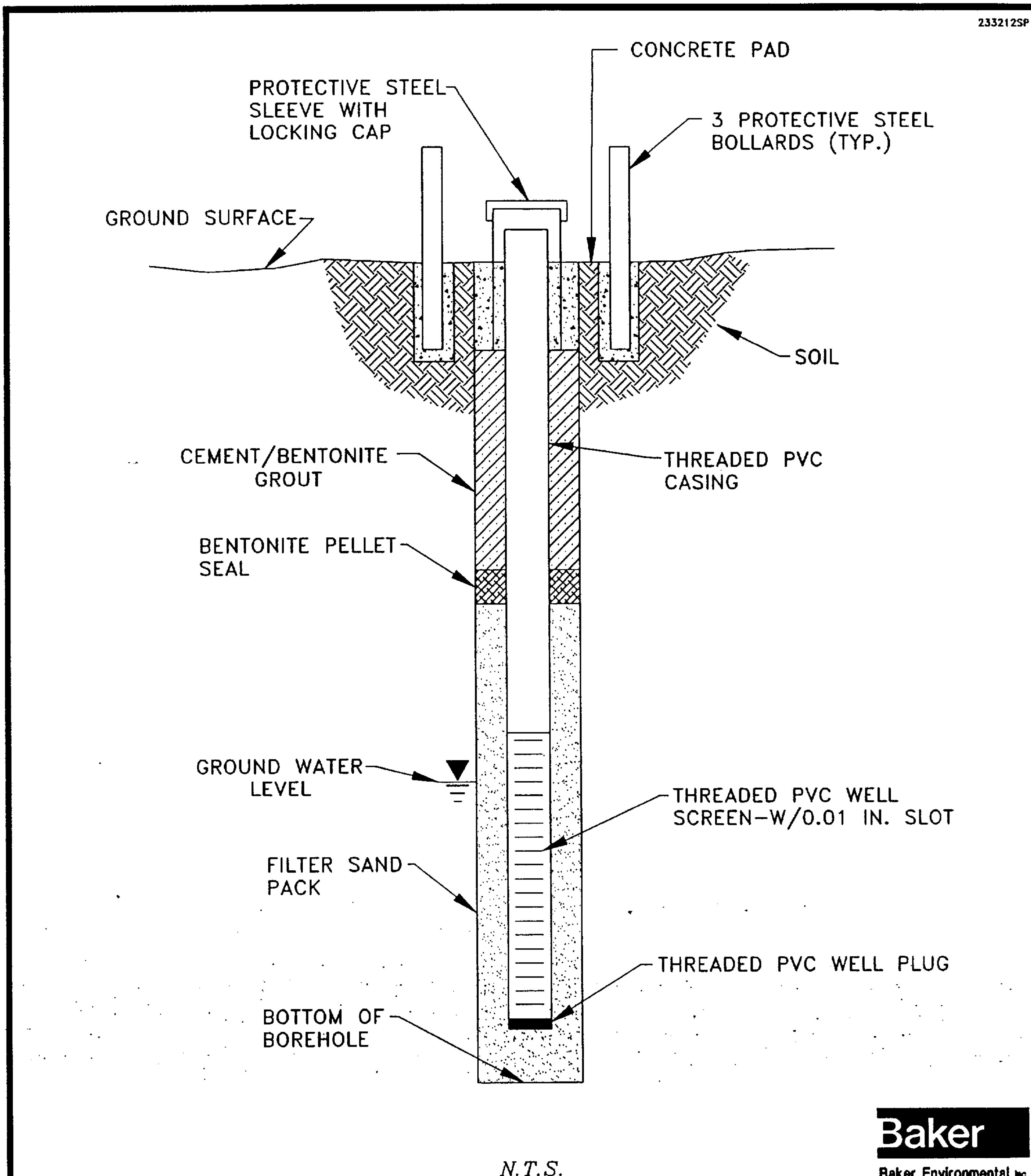


FIGURE 5-1
TYPICAL SHALLOW ABOVE GRADE TYPE II GROUNDWATER MONITORING WELL CONSTRUCTION DIAGRAM

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

two feet above the top of the screened interval. A lesser distance above the top of the screened interval may be packed with sand if the well is very shallow to allow for placement of sealing materials.

- A sodium bentonite seal at least 24-inch thick, unless shallow groundwater conditions are encountered, will be placed above the sand pack. The bentonite shall be allowed to hydrate for at least 8 hours before further completion of the well.

- The annular space above the bentonite seal will be backfilled with a cement-bentonite grout consisting of either two parts sand per one part of cement and water, or three to four percent bentonite powder (by dry weight) and seven gallons of potable water per 94 pound bag of portland cement.

- The depth intervals of all backfill materials shall be measured with a weighted measuring tape to the nearest 0.1 foot and recorded in the field logbook.

- The monitoring wells will be completed at the surface. The aboveground section of the PVC riser pipe will be protected by installation of a 4-inch diameter, 5-foot long steel casing (with locking cap and lock) into the cement grout. The bottom of the surface casing will be placed at a minimum of 2-1/2, but not more than 3-1/2 feet below the ground surface, as space permits. For very shallow wells, a steel casing of less than 5 feet in length may be used, as space permits. The protective steel casing shall not fully penetrate the bentonite seal.

- The top of each well will be protected with the installation of four, 3-inch diameter, 5-foot long steel pipes which will be installed around the outside of the concrete apron. The steel pipes shall be embedded to a minimum depth of 2.5 feet in 3,000 psi concrete. Each pipe shall also be filled with concrete. A concrete pad shall be placed at the same time the pipes are installed. The pad will be a minimum of 4-feet by 4-feet by 6-inches, extending two feet below the ground surface in the annular space and set two inches into the ground elsewhere. The protective casing and steel pipes will be painted with day-glo yellow paint, or equivalent.

- If necessary, in high-traffic areas, the monitoring well shall be completed at the surface using a "flush" man-hole type cover. If the well is installed through a paved or concrete surface, the annular space shall be grouted to a depth of at least 2.5-feet and the well shall be finished with a concrete collar. If the well has not been installed through a paved or concrete surface, the well shall be completed by construction of a concrete pad, a minimum of 4-feet by 4-feet by 6-inches, extending two feet below the ground surface in the annular space and set two inches into the ground elsewhere. If water table conditions prevent having a 24-inch bentonite seal and the concrete pad as specified, the concrete pad depth should be decreased. Two weep holes will be drilled into opposite sides of the protective casing just above the concrete pad. The concrete shall be crowned to meet the finished grade of the surrounding pavement, as required. If appropriate, the vault around the buried wellhead will have a water drain to the surrounding soil and a watertight cover.

- All wells will have a locking cap connected to the protective casing. Each well will be tagged which will contain general well construction information and marked as "Test Well - Not For Consumptive Use."

Figure 5-1 depicts a typical Type II shallow monitoring well construction diagram.

Procedures for the installation and construction of Type II intermediate wells are presented below:

- Activity personnel will approve all monitoring well locations. These locations will be installed free of underground or overhead utility lines.

- A borehole will be advanced initially using hollow stem augers to just below the water table (so that samples can be collected for laboratory analysis). The augers will be nominal 3/4-inch I.D. Continuous 2-foot split-spoon samples will be collected while the borehole is advanced. Samples will be collected according to the procedures outlined in Section 5.1.2.

- The borehole will be further advanced until completion using mud rotary drilling. The reason mud rotary drilling will be used is because of the unconsolidated formation and drilling depths anticipated. A tricon drill bit with a O.D. of 7-7/8 inches will be used for advancing the borehole.

- Split-spoon samples will be collected at approximate 5 to 10-foot intervals during borehole advancement (mud rotary drilling). If a clay layer is encountered which may serve as a potential confining unit, continuous samples will be collected to determine the thickness of the layer. At that time, a decision will be made as to whether a Type-III well will be installed (described in the next section). Samples will be collected according to the procedures outlined in Section 5.1.2.

- Upon completion of the borehole to the desired depth, monitoring well construction materials will be installed.

- PVC is the material selected for monitoring well construction. It was selected on the basis of its low cost, ease of use and flexibility. USEPA Region IV requires justification of using PVC.

- Ten to twenty feet of 2-inch I.D., Schedule 40, # 10 slot (0.010 inch) screen with a bottom cap will be installed. The final determination for the length of the screen will be decided in the field based on the thickness of the upper portion of the Castle Hayne formation.

- The annular space around the screen will be backfilled with a well-graded medium to coarse sand as (No. 1 or No. 2 silica sand) as the hollow-stem augers are being withdrawn from the borehole. Sand shall be placed from the bottom of the boring to approximately two feet above the top of the screened interval. A lesser distance above the top of the screened interval may be packed with sand if the well is very shallow to allow for placement of sealing materials.

- A sodium bentonite seal (typically bentonite pellets) at least 24-inch thick, unless shallow groundwater conditions are encountered, will be placed above the sand pack. The bentonite shall be allowed to hydrate for at least 2 hours before further completion of the well.

- The annular space above the bentonite seal will be backfilled with a cement-bentonite grout consisting of either two parts sand per one part of cement and water, or three to four percent bentonite powder (by dry weight) and seven gallons of potable water per 94 pound bag of portland cement. The bentonite seal shall be installed using a tremie pipe, if applicable depths are anticipated (i.e., greater than 25 feet).

- The depth intervals of all backfill materials shall be measured with a weighted measuring tape to the nearest 0.1 foot and recorded in the field logbook.

- The monitoring wells will be completed at the surface. The aboveground section of the PVC riser pipe will be protected by installation of a 4-inch diameter, 5-foot long steel casing (with locking cap and lock) into the cement grout. The bottom of the surface casing will be placed at a minimum of 2-1/2, but not more than 3-1/2 feet below the ground surface, as space permits. For very shallow wells, a steel casing of less than 5 feet in length may be used, as space permits. The protective steel casing shall not fully penetrate the bentonite seal.

- The top of each well will be protected with the installation of four, 3-inch diameter, 5-foot long steel pipes which will be installed around the concrete apron. The steel pipes shall be embedded to a minimum depth of 2.5 feet in 3,000 psi concrete. Each pipe shall also be filled with concrete. A concrete pad shall be placed at the same time the pipes are installed. The pad will be a minimum of 4-feet by 4-feet by 6-inches, extending two feet below the ground surface in the annular space and set two inches into the ground elsewhere. The protective casing and steel pipes will be painted with day-glo yellow paint, or equivalent.

- If necessary, in high-traffic areas, the monitoring well shall be completed at the surface using a "flush" man-hole type cover. If the well is installed through a paved or concrete surface, the annular space shall be grouted to a depth of at least 2.5 feet and the well shall be finished with a concrete collar. If the well has not been installed through a paved or concrete surface, the well shall be completed by construction of a concrete pad, a minimum of 4-feet by 4-feet 6-inches, extending two feet below the ground surface in the annular space and set two inches into the ground elsewhere. If water table conditions prevent having a 24-inch bentonite seal and the concrete pad as specified, the concrete pad depth should be decreased. Two weep holes will be drilled into opposite sides of the protective casing just above the concrete pad. The concrete shall be crowned to meet the finished grade of the surrounding pavement, as required. If appropriate, the vault around the buried wellhead will have a water drain to the surrounding soil and a watertight cover.

- All wells will have a locking cap connected to the protective casing. Each well will be tagged which will contain general well construction information and marked as "Test Well - Not for Consumptive Use."

Figure 5-2 depicts a typical Type II intermediate monitoring well construction diagram.

Procedures for the installation of temporary groundwater monitoring wells is as follows:

- The borehole for the well installation will be drilled with a 4" or 6" diameter hand auger. The total depth of the borehole will be a minimum of six (6) feet.

- Well construction materials will consist of a five (5) foot section of 2" I.D. PVC screen (0.01-inch slot), bottom cap, 2" I.D. PVC riser, sand, and bentonite pellets. The length of PVC riser will depend on the total depth of the borehole.

- Following the completion of the borehole, the PVC screen with bottom cap will be lowered into the borehole. The PVC riser will be attached and the assembly will be

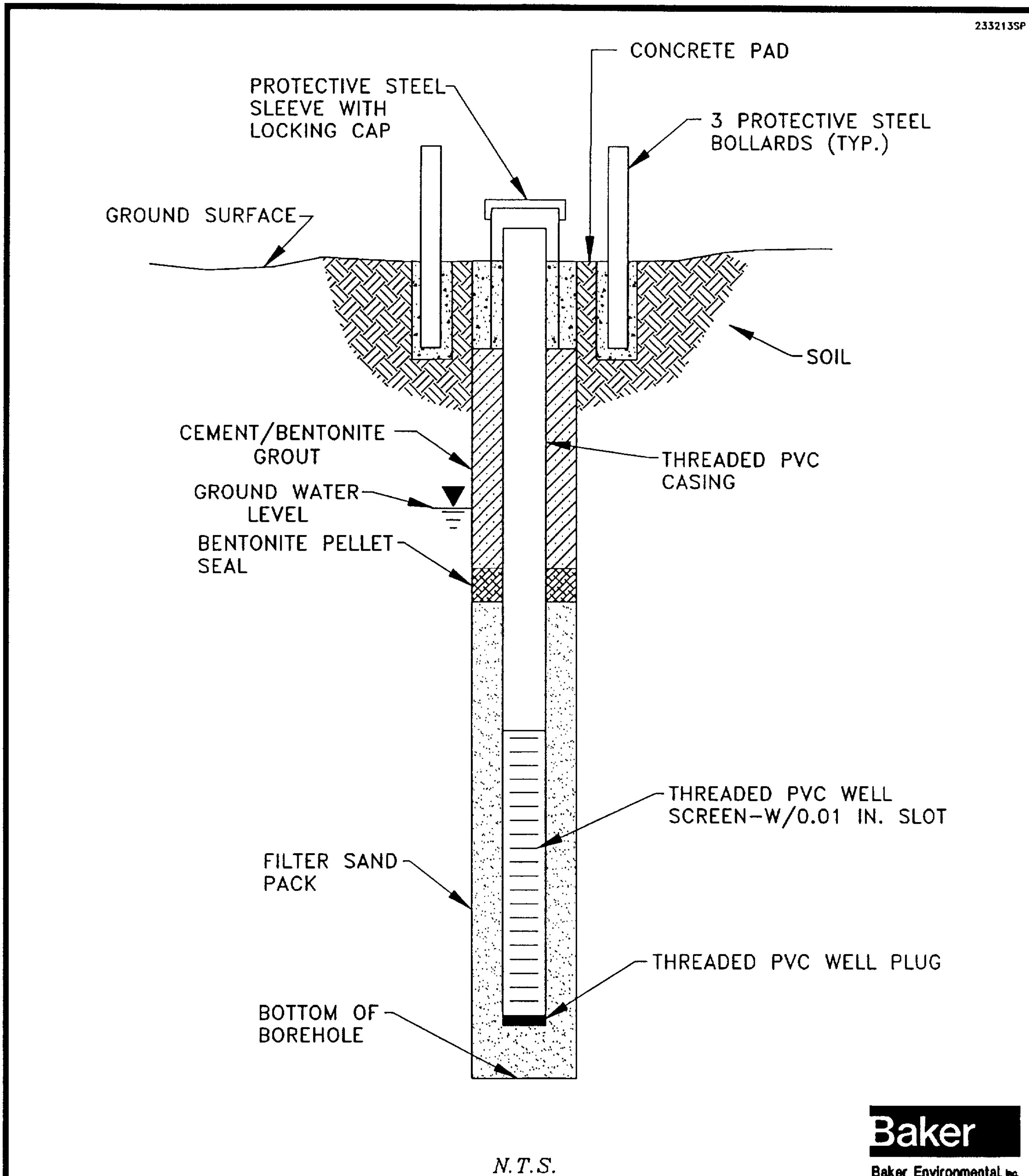


FIGURE 5-2
TYPICAL INTERMEDIATE ABOVE GRADE TYPE II GROUNDWATER MONITORING WELL CONSTRUCTION DIAGRAM

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

lowered to the bottom of the borehole. Enough riser will be attached to allow for a minimum two (2) foot stickup above the ground riser.

- The annular space around the well will be backfilled with a well graded medium to coarse sand, to a minimum of six (6) inches above the top of the screen. A bentonite seal will be placed above the sand backfill, a minimum of one (1) foot thick. No grout will be installed for a temporary well installation.

- Following the one round of sampling, these wells will be pulled and the boreholes backfilled with spoil material from the drilling of the borings.

All monitoring wells will be developed as specified in the ECBSOPQAM. The purposes of well development is to stabilize and increase the permeability of the filter pack around the well screen, to restore the permeability of the formation which may have been reduced by the drilling operations, and to remove fine-grained materials that may have entered the well or filter pack during installation. The selection of the well development method typically is based on drilling methods, well construction and installation details, and the characteristics of the formation.

Well development shall not be initiated until a minimum of 48 hours has elapsed subsequent to well completion. This time period will allow the cement grout to set. Shallow wells typically are developed using bailers or low-yield pumping in combination with surging using a surge block. Intermediate monitoring wells are developed using compressed air (equipped with an air filter) in combination with surging. Selection of a development device will be dependent on conditions encountered during monitoring well installation.

All wells shall be developed until well water runs relatively clear of fine-grained materials. Note that the water in some wells does not clear with continued development. Typical limits placed on well development may include any one of the following:

- Clarity of water based on visual determination

- A maximum time period (typically one hour for shallow wells)

- A maximum well volume (typically three to five well volumes)

- Stability of pH, specific conductance and temperature measurements (typically less than 10 percent change between three successive measurements)

- Clarity based on turbidity measurements [typically less than 50 Net Turbidity Units (NTU)]

A record of the well development shall be completed to document the development process.

Usually, a minimum period of one week should elapse between the end of initial development and the first sampling event for a well. This equilibration period allows groundwater unaffected by the installation of the well to occupy the vicinity of the screened interval. Details on SOPs for monitoring well installation can be found in Appendix C.

5.3 Groundwater Sample Collection (Task at Sites 16, 7, 80 and 3)

5.3.1 Groundwater Samples Collected from Monitoring Wells

Groundwater samples will be collected from existing and newly installed monitoring wells on site.

The collection of a groundwater sample includes the following steps:

1. First open the well cap and use volatile organic detection equipment (HNu or OVA) on the escaping gases at the well head to determine the need for respiratory protection. This task is usually performed by the Field Team Leader, Health and Safety Officer, or other designee.

2. When proper respiratory protection has been donned, sound the well for total depth and water level (decontaminated equipment) and record these data in the field logbook. Calculate the fluid volume in the well.

3. Lower purging equipment [teflon bailer or submersible pump (RediFlo-2® low yielding pumps)] into the well to a short distance below the water level and begin water removal. Purged water will be temporarily stored in DOT-approved 55-gallon drums. Final containment of purged water is addressed in Section 5.10.

4. Measure the rate of discharge using a bucket and stopwatch.

5. Purge a minimum of three to five well volumes before sampling. In low permeability strata (i.e., if the well is pumped to dryness), one volume will suffice. Allow the well to recharge as necessary, but preferably to 70 percent of the static water level, and then sample.

6. Record measurements of specific conductance, temperature, and pH during purging (i.e., after each volume has been removed) to ensure the groundwater stabilizes. Generally, these measurements are made after three, four, and five well volumes.

7. Lower the teflon bailer into the well, submerge into the groundwater, and retrieve. A teflon coated line (only the portion in contact with the water table) will be used for lowering the bailer. Pour groundwater from the bailer into the laboratory-supplied sample bottles.

8. Samples for VOC analysis will be collected first, followed by semivolatiles, PCBs, pesticides, and metals. Sample bottles will be filled in the same order for all monitoring wells.

9. Samples collected for dissolved metals analysis will be filtered in the field prior to being submitted for analysis. Filtering will be conducted using a 45-micron filter.

Sample preservation handling procedures are outlined in Section 6.0.

Appendix D presents the SOP for groundwater sampling.

5.4 Surface Water Sample Collection (Task at Sites 16 and 7)

The following procedures will be used for the collection of surface water samples at stations located on site. At each station, samples will be collected at the approximate mid-vertical point or near the bank of the surface water body. Care will be taken to ensure that the sampler does not contact and/or stir up the sediments, while still being relatively close to the sediment-water interface.

The surface water samples will be collected by dipping the laboratory-supplied sample bottles directly into the water. Clean PVC gloves will be worn by sampling personnel at each sampling station. For those sample bottles that contain preservative (e.g., sulfuric acid), the water will be collected in a clean, decontaminated sampling container, and then slowly transferred into the appropriate laboratory-supplied sample bottle.

The water samples will be collected from near mid-stream at each station, where applicable. Water samples at the furthest downstream station will be collected first, with subsequent samples taken at the next upstream station(s). Sediment samples will be collected after the water samples to minimize sediment disturbance and suspension.

All sample containers not containing preservative will be rinsed at least once with the sample water prior to final sample collection. In addition, the sampling container used to transfer the water into sample bottles containing preservatives will be rinsed once with sample water.

Care will be taken when collecting samples for analysis of volatile organics compounds (VOCs) to avoid excessive agitation that could result in loss of VOCs. VOC samples will be collected prior to the collection of the samples for analysis of the other parameters. Sample bottles will be filled in the same order at all sampling stations.

Temperature, pH, and specific conductance of the surface water will be measured in the field at each sampling location (at each sampling depth), immediately following sample collection.

The sampling location will be marked by placing a wooden stake and bright colored flagging at the nearest bank or shore. The sampling location will be marked with indelible ink on the stake. In addition, the distance from the shore and the approximate location will be estimated using triangulation methods, and recorded and sketched in the field log book. If permission is granted, photographs will be taken to document the physical and biological characteristics of the sampling location.

The following information will be recorded in the field logbook:

- Project location, date and time
- Weather
- Sample location, number, and identification number
- Flow conditions (i.e., high, low, in flood, etc.)
- On site water quality measurements
- Visual description of water (i.e., clear, cloudy, muddy, etc.)
- Sketch of sampling location including boundaries of the water body, sample location (and depth), relative position with respect to the site, location of wood identifier stake
- Names of sampling personnel
- Sampling technique, procedure, and equipment used

Sample preservation and handling procedures are outlined in Section 6.0.

Details on surface water sample acquisition are presented in Appendix E.

5.5 Sediment Sample Collection (Task at Sites 16 and 7)

The following procedures will be used for the collection of sediment samples at stations located on site. At each station, surface and near surface sediment samples will be collected at a depth of 0-6-inches, and 6-12-inches. These intervals of sediment will be collected using a stainless steel hand-held coring instrument. A new or decontaminated stainless steel liner tube, fitted with an eggshell catcher to prevent sample loss, will be used at each station.

The coring device will be pushed into the sediments to a minimum depth of 15-inches, or until refusal, whichever is encountered first. The sediments in the 0 to 6-inch interval and 6 to 12-inch interval will be extruded with a decontaminated extruder into the appropriate sample containers. If less than 12-inches of sediments are obtained, the first 6-inches will be placed in the 0 to 6-inch container, and the remaining sediment will be placed into the 6 to 12-inch container.

The sampling procedures for using the hand-held coring instrument (i.e., stainless-steel core sampler) are outlined below:

1. Inspect and prepare the corer:

    a. Inspect the core tube and, if one is being used, the core liner. Core tube and core liner must be firmly in place, free of obstruction throughout its length. Bottom edge of core tube, or of the nose piece, should be sharp and free of nicks or dents.

    b. Check the flutter valve for ease of movement.

    c. Check the flutter valve seat to make sure it is clear of any obstruction that could prevent a tight closure.

    d. Attach a line securely to the core sampler. The line should be free of any frayed or worn sections, and sufficiently long to reach bottom.

2. Get in position for the sampling operation -- keeping in mind that disturbance of the bottom area to be sampled should be avoided.

3. Line up the sampler, aiming it vertically for the point where the sample is to be taken.

4. Push the core sampler, in a smooth and continuous movement, through the water and into the sediments -- increasing the thrust as necessary to obtain the penetration desired.

5. If the corer has not been completely submerged, close the flutter valve by hand and press it shut while the sample is retrieved. Warning: the flutter valve must be kept very wet if it is to seal properly.

6. Lift the core sampler clear of the water, keeping it as nearly vertical as possible, and handle the sample according to the type of core tube.

7. Secure and identify the new sample. Unscrew the nose cone. Pull the liner out. Push out any extra sediments (greater than 12-inches). Push out the sediments within the 6 to 12-inch interval and place it in a sample jar. Push out the 0 to 6-inch sediment interval into another sample jar.

8. Seal all sample jars tightly.

9. Label all samples.

Appendix E presents the SOP for sediment sampling.

5.6 Land Survey

Each of the four SI sites require survey information. Horizontal and vertical survey tolerances are addressed within the survey requirements under Section 3.0, for each of the four sites. Appendix F provides a more detailed description of survey procedures and surveyor qualifications.

5.7 Monitoring and Data Collection Equipment

Field support activities and investigations will require the use of monitoring and data collection equipment. Specific conductance, temperature, and pH readings will be recorded during groundwater and surface water sample collection. In addition, similar specific conductance and pH readings will be recorded during well development. Appendix G, On-Site Water Quality Testing, provides specific procedures for collecting conductance, temperature, and pH readings.

Additional monitoring well information may be obtained using water level meters, water-product level meters, and well depth meters. The operation and various uses of this data collection equipment is provided in Appendix H.

Health and safety monitoring and environmental media screening will be conducted using a photoionization detector (PID) and a combustible gas/oxygen meters (O_2/LEL). The operation and use of the PID is described in Appendix I. The Bacharach O_2/LEL meter will also be used during the sampling program, primarily to monitor health and safety conditions. Appendix J provides a description of the Bacharach O_2/LEL meter and operating procedures.

5.8 Decontamination

Equipment and materials that require decontamination fall into two broad categories:

1. Field measurement, sampling, and monitoring equipment (e.g. water level meters, bailers, split-spoon samplers, hand auger buckets, stainless steel spoons, etc.)

2. Machinery, equipment, and materials (e.g. drilling rigs, backhoes, drilling equipment, monitoring well materials, etc.)

Appendices K and L detail procedures for decontaminating the two categories of equipment and materials, respectively.

6.0 SAMPLE HANDLING AND ANALYSIS

Field activities will be conducted in accordance with the USEPA Region IV Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual (February 1, 1991).

The number of samples, analytical methods, data quality level, and laboratory turnaround times are presented in Table 6-1. Preservation requirements and sample holding times are provided in Section 7.0 of the QAPP.

6.1 Sample Preservation and Handling

Sample preservation and handling procedures will be adhered to during the field program in order to maintain sample integrity. Preservation and handling procedures are provided in Appendix M of this FSAP.

6.2 Chain-of-Custody

Chain-of-custody procedures will be followed throughout the field program to ensure a documented, traceable link between measurement results and the sample or parameter they represent. These procedures are intended to provide a legally acceptable record of sample collection, identification, preparation, storage, shipping, and analysis. Chain-of-custody procedures to be followed during the field program are contained in Appendix N.

6.3 Field Logbook

Field logbooks will be used to record sampling activities and information. Logbooks will be copied and submitted to the field site manager for filing upon completion of the field program. Entries will include general sampling information so that site activities may be reconstructed. In addition to the field logbook, field forms (e.g. boring logs, well development records, etc) will be completed as support documentation for the field logbook. Appendix O describes the general format of the field logbook and applicable field forms.

TABLE 6-1

SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES
SITES 16, 7, 80, AND 3
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Study Area	Investigation	Baseline No. of Samples[1]	Analysis	Data Quality Objective	Analytical Method	Laboratory Turnaround
Site 16 - Montford Point Burn Dump	Soil - Burn Dump Boundary	22 borings/2 samples per boring	TCL Organics[2] TAL Metals[3]	III III	CLP/SOW CLP/SOW	Routine[4] Routine
	Soil - Well Borings	5 borings/2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Southeast Portion of Study Area	4 borings/2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Trenches	4 trenches/1 sample per trench (option)	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Background	3 borings/2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Groundwater - Two rounds sampling	6 new shallow monitoring wells	TCL Organics TAL Metals (total/dissolved)	III III	CLP/SOW CLP/SOW	Routine Routine
		1 sample	Engineering Parameters[5]	II	[5]	Routine
	Surface Water - Northeast Creek	5 stations	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Sediment - Northeast Creek	5 stations/2 samples per station	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine

TABLE 6-1 (Continued)

SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES
SITES 16, 7, 80, AND 3
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Study Area	Investigation	Baseline No. of Samples[1]	Analysis	Data Quality Objective	Analytical Method	Laboratory Turnaround
Site 7 - Tarawa Terrace Dump	Soil - Southwest Corner Trench	5 trenches/2 samples per trench	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Southwest Corner Boring	5 borings/2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Northwestern Boundary	23 borings/2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Community Center Playground	2 borings/1 sample per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Well Borings	2 borings/2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
		1 sample	Engineering Parameters	II	[5]	Routine
	Soil - Background	3 borings/2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Groundwater	5 (3 existing, 2 newly installed) shallow wells	TCL Organics TAL Metals (total/dissolved)	III III	CLP/SOW CLP/SOW	Routine Routine
		1 sample	Engineering Parameters	II	[5]	Routine
	Groundwater	3 temporary wells	TCL Organics TAL Metals (total/dissolved)	III III	CLP/SOW CLP/SOW	Routine Routine
	Surface Water - Northeast Creek	6 stations	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine

TABLE 6-1 (Continued)

SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES
SITES 16, 7, 80, AND 3
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Study Area	Investigation	Baseline No. of Samples[1]	Analysis	Data Quality Objective	Analytical Method	Laboratory Turnaround
Site 7 - Tarawa Terrace Dump (Continued)	Sediment - Northeast Creek	6 stations/2 samples per station	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Surface Water - Western Tributary	3 stations	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Sediment - Western Tributary	3 stations/1 sample per station	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Surface Water - Eastern Tributary	2 stations	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Sediment - Eastern Tributary	2 stations/1 sample per station	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Surface Water - Drainage Ditch	2 stations	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Sediment - Drainage Ditch	2 stations/1 sample per station	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Sediment - Marsh Area	4 stations/2 samples per station	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine

TABLE 6-1 (Continued)

SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES
SITES 16, 7, 80, AND 3
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Study Area	Investigation	Baseline No. of Samples[1]	Analysis	Data Quality Objective	Analytical Method	Laboratory Turnaround
Site 80 - Paradise Point Golf Course Maintenance Area	Soil - Lawn Area	7 borings/2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Between and around Buildings 1916 and 600	4 borings/2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Open Area of Soil Piles	7 boring/2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Mounded Area	10 borings/1 surface sample per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
		3 borings/1 subsurface sample per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Previous Drum Area	2 borings/1 surface sample per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Soil - Well Borings	5 borings/2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
		1 composite sample	Engineering Parameters	II	[5]	Routine
	Soil - Background	3 borings/2 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
	Groundwater	7 (3 existing shallow, 4 newly installed shallow, 1 newly installed intermediate)	TCL Organics TAL Metals (total/dissolved)	III III	CLP/SOW CLP/SOW	Routine Routine

TABLE 6-1 (Continued)

SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES
SITES 16, 7, 80, AND 3
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Study Area	Investigation	Baseline No. of Samples[1]	Analysis	Data Quality Objective	Analytical Method	Laboratory Turnaround
Site 3 - Old Creosote Plant	Soil - Northern Portion	13 borings/1 sample per boring	ENSYS PAH[6] ENSYS Petro Soil[7] TCL Semivolatile Organics[8]	II III	ENSYS CLP/SOW	 Routine
	Soil - Former Creosote Treatment Area	26 borings/1 sample per boring	ENSYS PAH ENSYS Petro Soil TCL Semivolatile Organics	II III	ENSYS CLP/SOW	 Routine
	Soil - Concrete Pads	8 borings/1 sample per boring	ENSYS PAH ENSYS Petro Soil TCL Semivolatile Organics	II III	ENSYS CLP/SOW	 Routine
	Soil - Railroad Spur	2 borings/1 sample per boring	ENSYS PAH ENSYS Petro Soil TCL Semivolatile Organics	II III	ENSYS CLP/SOW	 Routine
	Soil - Well Borings	4 shallow borings/3 samples per boring	TCL Semivolatile Organics	III	CLP/SOW CLP/SOW	Routine Routine
		1 intermediate boring/3 samples per boring	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine
		1 sample	Engineering Parameters	II	[5]	Routine
	Soil - Background	3 borings/1 sample per boring	TCL Semivolatile Organics	III	CLP/SOW CLP/SOW	Routine Routine
	Groundwater - 1 round of sampling	7 (3 existing, 4 newly installed shallow monitoring wells)	TCL Semivolatile Organics	III	CLP/SOW	Routine
		1 newly installed intermediate well	TCL Organics TAL Metals (total and dissolved)	III III	CLP/SOW CLP/SOW	Quick turn Quick turn

TABLE 6-1 (Continued)

SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES
SITES 16, 7, 80, AND 3
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0233
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Study Area	Investigation	Baseline No. of Samples[1]	Analysis	Data Quality Objective	Analytical Method	Laboratory Turnaround
Investigative Derived Waste	Development/Purge Water	4 (1 sample from each site)	TCL Organics TAL Metals	III III	CLP/SOW CLP/SOW	Routine Routine

(1) Baseline number of samples do not include QA/QC samples.

(2) TCL Organics: volatile organics, semivolatile organics, pesticides/PCBs

(3) TAL Inorganics:

Aluminum	EPA 3010/EPA 200.7	Cobalt	EPA 3010/EPA 200.7	Potassium	EPA 3010/EPA 200.7
Antimony	EPA 3010/EPA 200.7	Copper	EPA 3010/EPA 200.7	Selenium	EPA 3020/EPA 270.2
Arsenic	EPA 3020/EPA 206	Iron	EPA 3010/EPA 200.7	Silver	EPA 3010/EPA 200.7
Barium	EPA 3010/EPA 200.7	Lead	EPA 3020/EPA 239	Sodium	EPA 3010/EPA 200.7
Beryllium	EPA 3010/EPA 200.7	Magnesium	EPA 3010/EPA 200.7	Thallium	EPA 3020/EPA 279
Cadmium	EPA 3010/EPA 200.7	Manganese	EPA 3010/EPA 200.7	Vanadium	EPA 3010/EPA 200.7
Calcium	EPA 3010/EPA 200.7	Mercury	EPA 3010/EPA 245.1	Zinc	EPA 3010/EPA 200.7
Chromium	EPA 3010/EPA 200.7	Nickel	EPA 3010/EPA 200.7		

(4) Routine analytical turnaround is 28 days following receipt of samples.

(5) Engineering Parameters:

Soil:		Water:	
Atterburg Limits	ASTM D-4318-84	Microbial Count	
Particle Size Distribution	ASTM D-422-63	Biological Oxygen Demand (BOD_5)	EPA 405.1
Bulk Density	ASTM D-1557-91	Chemical Oxygen Demand (COD)	EPA 401.1
Soil Porosity		Nitrogen (NH_3)	EPA 350.1
Total Organic Carbon (TOC)	EPA 9060	Alkalinity	EPA 310.1
Redox Potential (Eh)		Total Dissolved Solids (TDS)	
		Total Suspended Solids (TSS)	

(6) ENSYS PAH

(7) ENSYS Petro Soil

(8) TCL Semivolatile Organics - Target Compound List Semivolatile Organics (CLP/SOW) includes acids, bases, and neutrals

(9) Newly installed monitoring wells at Site 3 will be on "quick turn"

(10) Full TCLP/RCRA

7.0 SITE MANAGEMENT

This section outlines the responsibilities and reporting requirements of on-site personnel.

7.1 Field Team Responsibilities

The field portion of this project will consist of one field team. All field activities will be coordinated by a Site Manager. The Site Manager will ensure that all field activities are conducted in accordance with the project plans (the Work Plan, this Field Sampling and Analysis Plan, the Quality Assurance Project Plan, and the Health and Safety Plan).

The Field Team will employ one or more drilling rigs for soil boring and monitoring well installation. Each rig(s) will be supervised by a Baker geologist. Two sampling technicians will be assigned to the field team. One of the sampling technicians will serve as the Site Health and Safety Officer.

7.2 Reporting Requirements

The Site Manager will report a summary of each day's field activities to the Project Manager or his/her designee. This may be done by telephone or telefax. The Site Manager will include, at a minimum, the following in his/her daily report:

- Baker personnel on site.
- Other personnel on site.
- Major activities of the day.
- Subcontractor quantities (e.g., drilling footages).
- Samples collected.
- Problems encountered.
- Planned activities.

The Site Manager will receive direction from the Project Manager regarding changes in scope of the investigation. All changes in scope will be discussed and agreed upon by LANTDIV, Camp Lejeune EMD, EPA Region IV, and the North Carolina DEHNR.

8.0 REFERENCES

U.S. Environmental Protection Agency (USEPA), 1992. Guidance for Performing Site Inspections Under CERCLA. Interim Final. Office of Emergency and Remedial Response, PB92-963375. EPA/540-R-92-021.

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Environmental Science and Engineering, Inc. (ESE), 1990. Final Site Summary Report, Marine Corps Base Camp Lejeune, North Carolina. Prepared for Naval Facilities Engineering Command Atlantic Division. ESE Project No. 49-02036. September 1990.

U.S. Environmental Protection Agency (USEPA), 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Interim Final. Office of Emergency and Remedial Response, OSWER Directive 9344.3-01. EPA/540/G-89-004.

Water and Air Research, Inc. (WAR), 1983. Initial Assessment Study of Marine Corps Base Camp Lejeune, North Carolina. Prepared for Naval Energy and Environmental Support Activity. April 1983.

APPENDIX A

Soil and Rock Sample Acquisition

SOIL AND ROCK SAMPLE ACQUISITION
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SOIL AND ROCK SAMPLE ACQUISITION

1.0 PURPOSE

The purpose of this procedure is to describe the handling of rock cores and subsurface soil samples collected during drilling operations. Surface soil sampling also is described.

2.0 SCOPE

The methods described in this SOP are applicable for the recovery of subsurface soil and rock samples acquired by coring operations or soil sampling techniques such as split-barrel sampling and thin-walled tube sampling. Procedures for the collection of surface soil samples also are discussed. This SOP does not discuss drilling techniques or well installation procedures. ASTM procedures for "Penetration Test and Split-Barrel Sampling of Soils," "Thin-Walled Tube Sampling of Soils," and "Diamond Core Drilling for Site Investigation" have been included as Attachments A through C, respectively.

3.0 DEFINITIONS

Thin-Walled Tube Sampler - A thin-walled metal tube (also called Shelby tube) used to recover relatively undisturbed soil samples. These tubes are available in various sizes, ranging from 2 to 5 inches outer diameter (O.D.) and 18 to 54 inches length. A stationary piston device is included in the sampler to reduce sample disturbance and increase recovery.

Split-Barrel Sampler - A steel tube, split in half lengthwise, with the halves held together by threaded collars at either end of the tube. Also called a split-spoon sampler, this device can be driven into unconsolidated materials using a drive weight mounted on the drilling string. A standard split-spoon sampler (used for performing Standard Penetration Tests) is two inches O.D. and 1-3/8-inches inner diameter (I.D.). This standard spoon is available in two common lengths providing either 20-inch or 26-inch internal longitudinal clearance for obtaining 18-inch or 24-inch long samples, respectively.

Grab Sample - An individual sample collected from a single location at a specific time or period of time generally not exceeding 15 minutes. Grab samples are associated with surface water, groundwater, wastewater, waste, contaminated surfaces, soil, and sediment sampling. Grab samples are typically used to characterize the media at a particular instant in time.

Composite Samples - A sample collected over time that typically consists of a series of discrete samples which are combined or "composited". Two types of composite samples are listed below:

- Areal Composite: A sample collected from individual grab samples collected on an areal or cross-sectional basis. Areal composites shall be made up of equal volumes of grab samples. Each grab sample shall be collected in an identical manner. Examples include sediment composites from quarter-point sampling of streams and soil samples from grid points.

- Vertical Composite: A sample collected from individual grab samples collected from a vertical cross section. Vertical composites shall be made up of equal volumes of grab samples. Each grab sample shall be collected in an identical manner. Examples include vertical profiles of soil/sediment columns, lakes and estuaries.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that, where applicable, project-specific plans are in accordance with these procedures, or that other approved procedures are developed. Furthermore, the Project Manager is responsible for development of documentation of procedures which deviate from those presented herein.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the specific sampling techniques and equipment to be used, and documenting these in the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Drilling Inspector - It is the responsibility of the drilling inspector to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The Drilling Inspector is responsible for the proper acquisition of rock cores and subsurface soil samples.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The sampling personnel are responsible for the proper acquisition of samples.

5.0 PROCEDURES

Subsurface soil and rock samples are used to characterize the three-dimensional subsurface stratigraphy. This characterization can indicate the potential for migration of contaminants from various sites. In addition, definition of the actual migration of contaminants can be obtained through chemical analysis of subsurface soil samples. Where the remedial activities may include in-situ treatment, or the excavation and removal of the contaminated soil, the depth and areal extent of contamination must be known as accurately as possible.

Surface soil samples serve to characterize the extent of surface contamination at various sites. These samples may be collected during initial site screening to determine gross contamination levels and levels of personal protection required as part of more intensive field sampling activities, to gather more detailed site data during design, or to determine the need for, or success of, cleanup actions.

Site construction activities may require that the engineering and physical properties of soil and rock be determined. Soil types, bearing strength, compressibility, permeability, plasticity, and moisture content are some of the geotechnical characteristics that may be determined by laboratory tests of soil samples. Rock quality, strength, stratigraphy, structure, etc. often are needed to design and construct deep foundations or remedial components.

5.1 Rock Cores

Once rock coring has been completed and the core recovered, the rock core must be carefully removed from the barrel, placed in a core tray (previously labeled "top" and "bottom" to avoid confusion), classified, and measured for percentage of recovery, as well as the rock quality designation (RQD) (see SOP F101). If split-barrels are used, the core may be measured and classified in the split barrel after opening and then transferred to a core box.

Each core shall be described and classified on a Field Test Boring Record using a uniform system as presented in SOP F101. If moisture content will be determined or if it is desirable to prevent drying (e.g., to prevent shrinkage of hydrated formations) or oxidation of the core, the core must be wrapped in plastic sleeves immediately after logging. Each plastic sleeve shall be labeled with indelible ink. The boring number, run number and the footage represented in each sleeve shall be included, as well as the top and bottom of the core run.

After sampling, rock cores must be placed in the sequence of recovery in wooden or plastic core boxes provided by the drilling contractor. Rock cores from two different borings shall not be placed in the same core box. The core boxes should be constructed to accommodate at least 20 linear feet of core in rows of approximately five feet each and should be constructed with hinged tops secured with screws, and a latch (usually a hook and eye) to keep the top securely fastened. Wood partitions shall be placed at the end of each core run and between rows. The depth from the surface of the boring to the top and bottom of the drill run and the run number shall be marked on the wooden partitions with indelible ink. The order of placing cores shall be the same in all core boxes. The top of each core obtained should be clearly and permanently marked on each box. The width of each row must be compatible with the core diameter to prevent lateral movement of the core in the box. Similarly, any empty space in a row shall be filled with an appropriate filler material or spacers to prevent longitudinal movement of the core in the box.

The inside and outside of the core-box lid shall be marked by indelible ink to show all pertinent data pertaining to the box's contents. At a minimum, the following information must be included:

- Project name
- Date
- CTO number
- Boring number
- Footage (depths)
- Run number(s)
- Recovery
- Rock Quality Designation (RQD)
- Box number (x of x)

It is also useful to draw a large diagram of the core in the box, on the inside of the box top. This provides more room for elevations, run numbers, recoveries, comments, etc., than could be entered on the upper edges of partitions or spaces in the core box.

For easy retrieval when core boxes are stacked, the sides and ends of the box should also be labeled and include CTO number, boring number, top and bottom depths of core and box number.

Due to the weight of the core, a filled core box should always be handled by two people. Core boxes stored on site should be protected from the weather. The core boxes should be removed from the site in a careful manner as soon as possible. Exposure to extreme heat or cold should be avoided whenever possible.

5.2 Subsurface Soil Samples

This section discusses three methods for collecting subsurface soil samples: (1) split-spoon sampling; (2) shelby tube sampling; and, (3) bucket auger sampling. All three methods yield samples suitable for laboratory analysis. Copies of the ASTM procedures for split-spoon sampling and shelby-tube sampling are provided in Attachments A and B, respectively.

5.2.1 Split-Barrel (Split-Spoon) Sampling

The following procedures are to be used for split-spoon, geotechnical soil sampling:

1. Clean out the borehole to the desired sampling depth using equipment that will ensure that the material to be sampled is not disturbed by the operation.

2. Side-discharge bits are permissible. A bottom-discharge bit should not be used. The process of jetting through the sampler and then sampling when the desired depth is reached shall not be permitted. Where casing is used, it may not be driven below the sampling elevation.

3. The two-inch O.D. split-barrel sampler should be driven with blows from a 140-pound hammer falling 30 inches in accordance with ASTM D1586-84, Standard Penetration Test.

4. Repeat this operation at intervals not longer than 5 feet in homogeneous strata, or as specified in the Sampling and Analysis Plan.

5. Record on the Field Test Boring Record or field logbook the number of blows required to effect each six inches of penetration or fraction thereof. The first six inches is considered to be a seating drive. The sum of the number of blows required for the

second and third six inches of penetration is termed the penetration resistance, N. If the sampler is driven less than 18 inches, the penetration resistance is that for the last one foot of penetration. (If less than one foot is penetrated, the logs shall state the number of blows and the fraction of one foot penetrated.) In cases where samples are driven 24 inches, the sum of second and third six-inch increments will be used to calculate the penetration resistance. (Refusal of the SPT will be noted as 50 blows over an interval equal to or less than 6 inches; the interval driven will be noted with the blow count.)

6. Bring the sampler to the surface and remove both ends and one half of the split-spoon such that the soil recovered rests in the remaining half of the barrel. Describe carefully the recovery (length), composition, structure, consistency, color, condition, etc. of the recovered soil according to SOP F101; then put into jars without ramming. Jars with samples not taken for chemical analysis should be sealed with wax, or hermetically sealed (using a teflon cap liner) to prevent evaporation of the soil moisture. Affix labels to the jar and complete Chain-of-Custody and other required sample data forms (see SOP F302). Protect samples against extreme temperature changes and breakage by placing them in appropriate cartons stored in a protected area.

7. Split-spoon samplers shall be decontaminated after each use and prior to the initial use at a site according to SOP F501.

In addition to collecting soils for geotechnical purposes, split-spoon sampling can be employed to obtain samples for environmental analytical analysis. The following procedures are to be used for split-spoon, environmental soil sampling:

1. Follow sample collection procedures 1 through 6 as outlined in Section 5.2.1.

2. After sample collection, remove the soil from the split-spoon sampler. Prior to filling laboratory containers, the soil sample should be mixed thoroughly as possible to ensure that the sample is as representative as possible of the sample interval. Soil samples for volatile organic compounds should <u>not</u> be mixed. Further, sample containers for volatile organic compounds analyses should be filled completely without head space remaining in the container to minimize volatilization.

3. Record all pertinent sampling information such as soil description, sample depth, sample number, sample location, and time of sample collection in the Field Test Boring Record or field logbook. In addition, label, tag, and number the sample bottle(s).

4. Pack the samples for shipping (see SOP F300). Attach seal to the shipping package. Make sure that Chain-of-Custody Forms and Sample Request Forms are properly filled out and enclosed or attached (see SOP F301).

5. Decontaminate the split-spoon sample as described in SOP F501. Replace disposable latex gloves between sample stations to prevent cross-contaminating samples.

For obtaining composite soil samples (see Definitions), a slightly modified approach is employed. Each individual discrete soil sample from the desired sample interval will be placed into a stainless-steel, decontaminated bowl prior to filling the laboratory sample containers. Special care should be taken to cover the bowl between samples with aluminum foil to minimize volatilization. Immediately after obtaining soils from the desired sampling interval, the sample to be analyzed for Volatile Organic Compounds (VOCs) should be collected. Care should be taken to obtain a representative sampling of each sample interval. The remaining soils should be thoroughly mixed. Adequate mixing can be achieved by stirring in a circular fashion and occasionally turning the soils over. Once the remaining soils have been thoroughly combined, samples for analyses other than VOCs should be placed into the appropriate sampling containers.

5.2.2 Thin-Wall (Shelby Tube) Sampling

When it is desired to take undisturbed samples of soil for physical laboratory testing, thin-walled seamless tube samplers (Shelby tubes) will be used. The following method applies:

1. Clean out the hole to the sampling elevation, being careful to minimize the chance for disturbance or contamination of the material to be sampled.

2. The use of bottom discharge bits or jetting through an open-tube sampler to clean out the hole shall not be allowed. Any side discharge bits are permitted.

3. The sampler must be of a stationary piston-type, to limit sample disturbance and aid in retaining the sample. Either the hydraulically operated or control rod activated-type of stationary piston sampler may be used. Prior to inserting the tube sampler in the hole, check to ensure that the sampler head contains a check valve. The check valve is necessary to keep water in the rods from pushing the sample out of the tube sampler during sample withdrawal and to maintain a suction within the tube to help retain the sample.

4. With the sampling tube resting on the bottom of the hole and the water level in the boring at the natural groundwater level or above, push the tube into the soil by a continuous and rapid motion, without impacting or twisting. In no case shall the tube be pushed further than the length provided for the soil sample. Allow a free space in the tube for cuttings and sludge.

5. After pushing the tube, the sample should sit 5 to 15 minutes prior to removal. Immediately before removal, the sample must be sheared by rotating the rods with a pipe wrench a minimum of two revolutions.

6. Upon removal of the sampler tube from the hole, measure the length of sample in the tube and also the length penetrated. Remove disturbed material in the upper end of the tube and measure the length of sample again. After removing at least an inch of

soil, from the lower end and after inserting an impervious disk, seal both ends of the tube with at least a 1/2-inch thickness of wax applied in a way that will prevent the wax from entering the sample. Newspaper or other types of filler must be placed in voids at either end of the sampler prior to sealing with wax. Place plastic caps on the ends of the sampler, tape them into place and then dip the ends in wax to seal them.

7. Affix labels to the tubes and record sample number, depth, penetration, and recovery length on the label. Mark the same information and "up" direction on the tube with indelible ink, and mark the end of the sample. Complete chain-of-custody and other required forms (see SOP F302). Do not allow tubes to freeze, and store the samples vertically (with the same orientation they had in the ground, i.e., top of sample is up) in a cool place out of the sun at all times. Ship samples protected with suitable resilient packing material to reduce shock, vibration, and disturbance.

8. From soil removed from the ends of the tube, make a careful description using the methods presented in SOP F101.

9. When thin-wall tube samplers are used to collect soil for certain chemical analyses, it may be necessary to avoid using wax, newspaper, or other fillers. The SAP for each site should address specific materials allowed dependent on analytes being tested.

Thin-walled undisturbed tube samplers are restricted in their usage by the consistency of the soil to be sampled. Often very loose and/or wet samples cannot be retrieved by the samplers, and soils with a consistency in excess of very stiff cannot be penetrated by the sampler. Devices such as Dension or Pitcher cores can be used in conjunction with the tube samplers to obtain undisturbed samples of stiff soils. Using these devices normally increases sampling costs and, therefore, their use should be weighed against the increased cost and the need for an undisturbed sample. In any case, if a sample cannot be obtained with a tube sampler, an attempt should be made with a split-spoon sampler at the same depth so that at least one sample can be obtained for classification purposes.

5.2.3 Bucket (Hand) Auger Sampling

Hand augering is the most common manual method used to collect subsurface samples. Typically, 4-inch auger buckets with cutting heads are pushed and twisted into the ground and removed as the buckets are filled. The auger holes are advanced one bucket at a time. The practical depth of investigation using a hand auger is related to the material being sampled. In sands, augering is usually easily accomplished, but the depth of investigation is controlled by the depth at which sands begin to cave. At this point, auger holes usually begin to collapse and cannot practically be advanced to lower depths, and further samples, if required, must be collected using some type of pushed or driven device. Hand augering may also become difficult in tight clays or cemented sands. At depths approaching 20 feet, torquing of hand auger extensions becomes so severe that in resistant materials, powered methods must be used if deeper samples are required.

When a vertical sampling interval has been established, one auger bucket is used to advance the auger hole to the first desired sampling depth. If the sample at this location is to be a vertical composite of all intervals, the same bucket may be used to advance the hole, as well collect subsequent samples in the same hole. However, if discrete grab samples are to be collected to characterize each depth, a new bucket must be placed on the end of the auger extension immediately prior to collecting the next sample. The top several inches of soil should be removed from the bucket to minimize the chances of cross-contamination of the sample from fall-in of material from the upper portions of the hole. The bucket auger should be decontaminated between samples as outlined in SOP F502.

In addition to hand augering, powered augers can be used to advance a boring for subsurface soil collection. However, this type of equipment is technically a sampling aid and not a sampling device, and 20 to 25 feet is the typical lower depth range for this equipment. It is used to advance a hole to the required sample depth, at which point a hand auger is usually used to collect the sample.

5.3 Surface Soil Samples

Surface soils are generally classified as soils between the ground surface and 6 to 12 inches below ground surface. For loosely packed surface soils, stainless steel (organic analyses) or plastic (inorganic analyses) scoops or trowels, can be used to collect representative samples. For densely packed soils or deeper soil samples, a hand or power soil auger may be used.

The following methods are to be used:

1. Use a soil auger for deep samples (greater than 12 inches) or a scoop or trowel for surface samples. Remove debris, rocks, twigs, and vegetation before collecting the sample.
2. Immediately transfer the sample to the appropriate sample container. Attach a label and identification tag. Record all required information in the field logbook and on the sample log sheet, chain-of-custody record, and other required forms.

3. Classify and record a description of the sample, as discussed in SOP F101. Descriptions for surface soil samples should be recorded in the field logbook; descriptions for soil samples collected with power or hand augers shall be recorded on a Field Test Boring Record.

4. Store the sampling utensil in a plastic bag until decontamination or disposal. Use a new or freshly-decontaminated sampling utensil for each sample taken.

5. Pack and ship as described in SOP F304.

6. Mark the location with a numbered stake if possible and locate sample points on a sketch of the site or on a sketch in the field logbook.

7. When a representative composited sample is to be prepared (e.g., samples taken from a gridded area or from several different depths), it is best to composite individual samples in the laboratory where they can be more precisely composited on a weight or volume basis. If this is not possible, the individual samples (all of equal volume, i.e., the sample bottles should be full) should be placed in a stainless steel bucket, mixed thoroughly using a stainless steel spatula or trowel, and a composite sample collected. In some cases, as delineated in project-specific sampling and analysis plans, laboratory compositing of the samples may be more appropriate than field compositing. Samples to be analyzed for parameters sensitive to volatilization should be composited and placed into the appropriate sample bottles immediately upon collection.

6.0 QUALITY ASSURANCE RECORDS

Where applicable, Field Test Boring Records and Test Boring Records will serve as the quality assurance records for subsurface soil samples, rock cores and near surface soil samples collected with a hand or power auger. Observations shall be recorded in the Field Logbook as described in SOP F303. Chain-of-Custody records shall be completed for samples collected for laboratory analysis as described in SOP F302.

7.0 REFERENCES

1. American Society for Testing and Materials, 1987. Standard Method for Penetration Test and Split-Barrel Sampling of Soils. ASTM Method D1586-84, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

2. American Society for Testing and Materials, 1987. Standard Practice for Thin-Walled Tube Sampling of Soils. Method D1587-83, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

3. American Society for Testing and Materials, 1987. Standard Practice for Diamond Core Drilling for Site Investigation. Method D2113-83 (1987), Annual Book of Standards ASTM, Philadelphia, Pennsylvania.

4. U. S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA, Environmental Services Division, Athens, Georgia.

ATTACHMENT A

ASTM D1586-84

STANDARD METHOD FOR PENETRATION TEST AND SPLIT-BARREL SAMPLING OF SOILS

Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils[1]

This standard is issued under the fixed designation D 1586; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. Consult the DOD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

$^{\epsilon 1}$ NOTE—Editorial changes were made throughout October 1992.

1. Scope

1.1 This test method describes the procedure, generally known as the Standard Penetration Test (SPT), for driving a split-barrel sampler to obtain a representative soil sample and a measure of the resistance of the soil to penetration of the sampler.

1.2 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For a specific precautionary statement, see 5.4.1.

1.3 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

D 2487 Test Method for Classification of Soils for Engineering Purposes[2]

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[2]

D 4220 Practices for Preserving and Transporting Soil Samples[2]

D 4633 Test Method for Stress Wave Energy Measurement for Dynamic Penetrometer Testing Systems[2]

3. Terminology

3.1 *Descriptions of Terms Specific to This Standard*

3.1.1 *anvil*—that portion of the drive-weight assembly which the hammer strikes and through which the hammer energy passes into the drill rods.

3.1.2 *cathead*—the rotating drum or windlass in the rope-cathead lift system around which the operator wraps a rope to lift and drop the hammer by successively tightening and loosening the rope turns around the drum.

3.1.3 *drill rods*—rods used to transmit downward force and torque to the drill bit while drilling a borehole.

3.1.4 *drive-weight assembly*—a device consisting of the hammer, hammer fall guide, the anvil, and any hammer drop system.

3.1.5 *hammer*—that portion of the drive-weight assembly consisting of the 140 ± 2 lb (63.5 ± 1 kg) impact weight which is successively lifted and dropped to provide the energy that accomplishes the sampling and penetration.

3.1.6 *hammer drop system*—that portion of the drive-weight assembly by which the operator accomplishes the lifting and dropping of the hammer to produce the blow.

3.1.7 *hammer fall guide*—that part of the drive-weight assembly used to guide the fall of the hammer.

3.1.8 *N-value*—the blowcount representation of the penetration resistance of the soil. The *N*-value, reported in blows per foot, equals the sum of the number of blows required to drive the sampler over the depth interval of 6 to 18 in. (150 to 450 mm) (see 7.3).

3.1.9 ΔN—the number of blows obtained from each of the 6-in. (150-mm) intervals of sampler penetration (see 7.3).

3.1.10 *number of rope turns*—the total contact angle between the rope and the cathead at the beginning of the operator's rope slackening to drop the hammer, divided by 360° (see Fig. 1).

3.1.11 *sampling rods*—rods that connect the drive-weight assembly to the sampler. Drill rods are often used for this purpose.

3.1.12 *SPT*—abbreviation for Standard Penetration Test, a term by which engineers commonly refer to this method.

4. Significance and Use

4.1 This test method provides a soil sample for identification purposes and for laboratory tests appropriate for soil obtained from a sampler that may produce large shear strain disturbance in the sample.

4.2 This test method is used extensively in a great variety of geotechnical exploration projects. Many local correlations and widely published correlations which relate SPT blowcount, or *N*-value, and the engineering behavior of earthworks and foundations are available.

5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment that provides at the time of sampling a suitably clean open hole before insertion of the sampler and ensures that the penetration test is performed on undisturbed soil shall be acceptable. The following pieces of equipment have proven to be

[1] This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

Current edition approved Sept. 11, 1984. Published November 1984. Originally published as D 1586 – 58 T. Last previous edition D 1586 – 67 (1974).

[2] *Annual Book of ASTM Standards*, Vol 04.08.

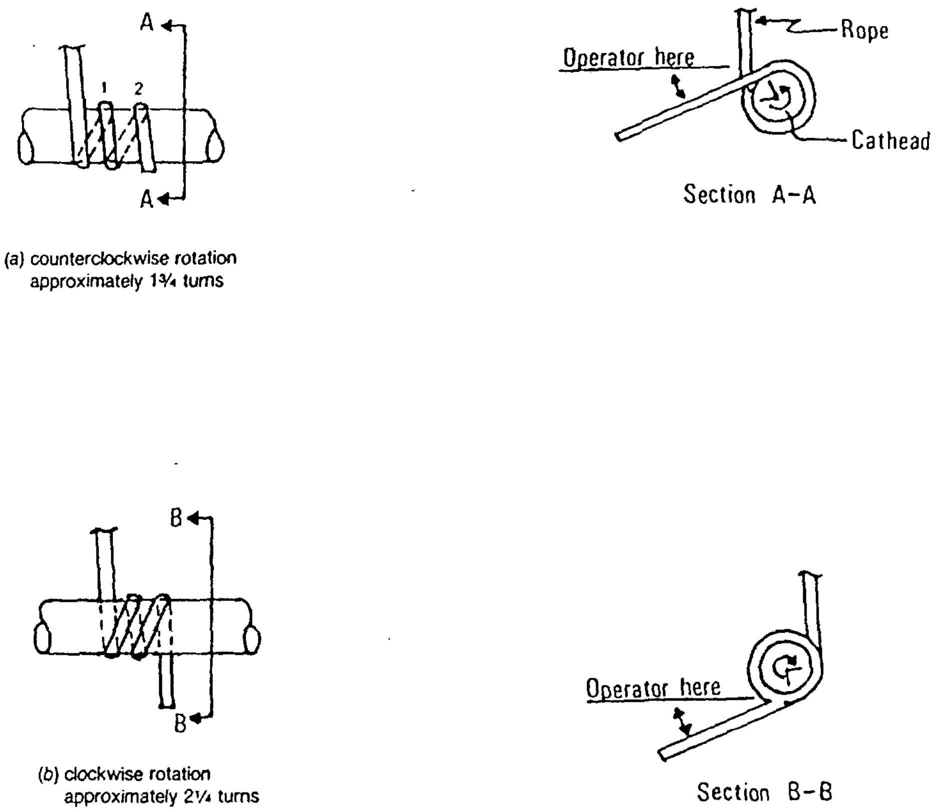


FIG. 1 Definitions of the Number of Rope Turns and the Angle for (a) Counterclockwise Rotation and (b) Clockwise Rotation of the Cathead

suitable for advancing a borehole in some subsurface conditions.

5.1.1 *Drag, Chopping, and Fishtail Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjuction with open-hole rotary drilling or casing-advancement drilling methods. To avoid disturbance of the underlying soil, bottom discharge bits are not permitted; only side discharge bits are permitted.

5.1.2 *Roller-Cone Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advancement drilling methods if the drilling fluid discharge is deflected.

5.1.3 *Hollow-Stem Continuous Flight Augers*, with or without a center bit assembly, may be used to drill the boring. The inside diameter of the hollow-stem augers shall be less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm).

5.1.4 *Solid, Continuous Flight, Bucket and Hand Augers*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used if the soil on the side of the boring does not cave onto the sampler or sampling rods during sampling.

5.2 *Sampling Rods*—Flush-joint steel drill rods shall be used to connect the split-barrel sampler to the drive-weight assembly. The sampling rod shall have a stiffness (moment of inertia) equal to or greater than that of parallel wall "A" rod (a steel rod which has an outside diameter of 1⅝ in. (41.2 mm) and an inside diameter of 1⅛ in. (28.5 mm).

NOTE 1—Recent research and comparative testing indicates the type rod used, with stiffness ranging from "A" size rod to "N" size rod, will usually have a negligible effect on the *N*-values to depths of at least 100 ft (30 m).

5.3 *Split-Barrel Sampler*—The sampler shall be constructed with the dimensions indicated in Fig. 2. The driving shoe shall be of hardened steel and shall be replaced or repaired when it becomes dented or distorted. The use of liners to produce a constant inside diameter of 1⅜ in. (35 mm) is permitted, but shall be noted on the penetration record if used. The use of a sample retainer basket is permitted, and should also be noted on the penetration record if used.

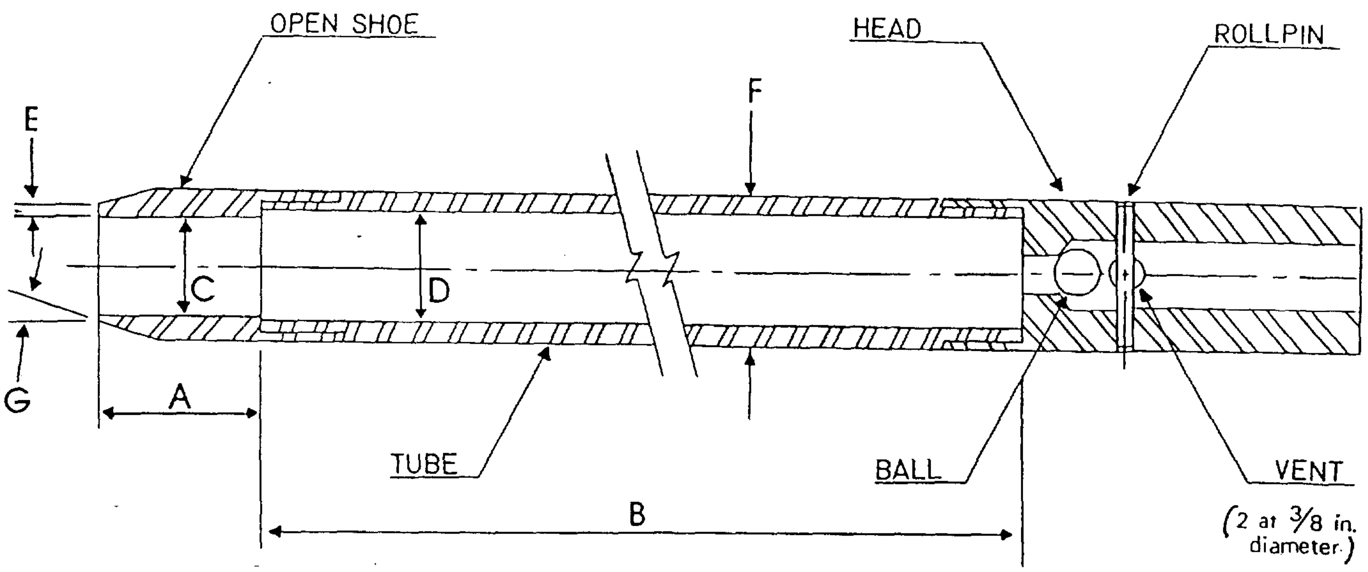
NOTE 2—Both theory and available test data suggest that *N*-values may increase between 10 to 30 % when liners are used.

5.4 *Drive-Weight Assembly:*

5.4.1 *Hammer and Anvil*—The hammer shall weigh 140 ± 2 lb (63.5 ± 1 kg) and shall be a solid rigid metallic mass. The hammer shall strike the anvil and make steel on steel contact when it is dropped. A hammer fall guide permitting a free fall shall be used. Hammers used with the cathead and rope method shall have an unimpeded overlift capacity of at least 4 in. (100 mm). For safety reasons, the use of a hammer assembly with an internal anvil is encouraged.

NOTE 3—It is suggested that the hammer fall guide be permanently marked to enable the operator or inspector to judge the hammer drop height.

5.4.2 *Hammer Drop System*—Rope-cathead, trip, semi-automatic, or automatic hammer drop systems may be used, providing the lifting apparatus will not cause penetration of



A = 1.0 to 2.0 in. (25 to 50 mm)
B = 18.0 to 30.0 in. (0.457 to 0.762 m)
C = 1.375 ± 0.005 in. (34.93 ± 0.13 mm)
D = 1.50 ± 0.05 − 0.00 in. (38.1 ± 1.3 − 0.0 mm)
E = 0.10 ± 0.02 in. (2.54 ± 0.25 mm)
F = 2.00 ± 0.05 − 0.00 in. (50.8 ± 1.3 − 0.0 mm)
G = 16.0° to 23.0°

The 1½ in. (38 mm) inside diameter split barrel may be used with a 16-gage wall thickness split liner. The penetrating end of the drive shoe may be slightly rounded. Metal or plastic retainers may be used to retain soil samples.

FIG. 2 Split-Barrel Sampler

the sampler while re-engaging and lifting the hammer.

5.5 *Accessory Equipment*—Accessories such as labels, .mple containers, data sheets, and groundwater level measuring devices shall be provided in accordance with the requirements of the project and other ASTM standards.

6. Drilling Procedure

6.1 The boring shall be advanced incrementally to permit intermittent or continuous sampling. Test intervals and locations are normally stipulated by the project engineer or geologist. Typically, the intervals selected are 5 ft (1.5 mm) or less in homogeneous strata with test and sampling locations at every change of strata.

6.2 Any drilling procedure that provides a suitably clean and stable hole before insertion of the sampler and assures that the penetration test is performed on essentially undisturbed soil shall be acceptable. Each of the following procedures have proven to be acceptable for some subsurface conditions. The subsurface conditions anticipated should be considered when selecting the drilling method to be used.

6.2.1 Open-hole rotary drilling method.

6.2.2 Continuous flight hollow-stem auger method.

6.2.3 Wash boring method.

6.2.4 Continuous flight solid auger method.

6.3 Several drilling methods produce unacceptable borings. The process of jetting through an open tube sampler and then sampling when the desired depth is reached shall not be permitted. The continuous flight solid auger method shall not be used for advancing the boring below a water le or below the upper confining bed of a confined ..on-cohesive stratum that is under artesian pressure. Casing may not be advanced below the sampling elevation prior to sampling. Advancing a boring with bottom discharge bits is not permissible. It is not permissible to advance the boring for subsequent insertion of the sampler solely by means of previous sampling with the SPT sampler.

6.4 The drilling fluid level within the boring or hollow-stem augers shall be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling.

7. Sampling and Testing Procedure

7.1 After the boring has been advanced to the desired sampling elevation and excessive cuttings have been removed, prepare for the test with the following sequence of operations.

7.1.1 Attach the split-barrel sampler to the sampling rods and lower into the borehole. Do not allow the sampler to drop onto the soil to be sampled.

7.1.2 Position the hammer above and attach the anvil to the top of the sampling rods. This may be done before the sampling rods and sampler are lowered into the borehole.

7.1.3 Rest the dead weight of the sampler, rods, anvil, and drive weight on the bottom of the boring and apply a seating blow. If excessive cuttings are encountered at the bottom of the boring, remove the sampler and sampling rods from the boring and remove the cuttings.

7.1.4 Mark the drill rods in three successive 6-in. (0.15-m) increments so that the advance of the sampler under the impact of the hammer can be easily observed for each 6-in. (0.15-m) increment.

7.2 Drive the sampler with blows from the 140-lb (63.5-

kg) hammer and count the number of blows applied in each 6-in. (0.15-m) increment until one of the following occurs:

7.2.1 A total of 50 blows have been applied during any one of the three 6-in. (0.15-m) increments described in 7.1.4.

7.2.2 A total of 100 blows have been applied.

7.2.3 There is no observed advance of the sampler during the application of 10 successive blows of the hammer.

7.2.4 The sampler is advanced the complete 18 in. (0.45 m) without the limiting blow counts occurring as described in 7.2.1, 7.2.2, or 7.2.3.

7.3 Record the number of blows required to effect each 6 in. (0.15 m) of penetration or fraction thereof. The first 6 in. is considered to be a seating drive. The sum of the number of blows required for the second and third 6 in. of penetration is termed the "standard penetration resistance," or the "*N*-value." If the sampler is driven less than 18 in. (0.45 m), as permitted in 7.2.1, 7.2.2, or 7.2.3, the number of blows per each complete 6-in. (0.15-m) increment and per each partial increment shall be recorded on the boring log. For partial increments, the depth of penetration shall be reported to the nearest 1 in. (25 mm), in addition to the number of blows. If the sampler advances below the bottom of the boring under the static weight of the drill rods or the weight of the drill rods plus the static weight of the hammer, this information should be noted on the boring log.

7.4 The raising and dropping of the 140-lb (63.5-kg) hammer shall be accomplished using either of the following two methods:

7.4.1 By using a trip, automatic, or semi-automatic hammer drop system which lifts the 140-lb (63.5-kg) hammer and allows it to drop 30 ± 1.0 in. (0.76 m ± 25 mm) unimpeded.

7.4.2 By using a cathead to pull a rope attached to the hammer. When the cathead and rope method is used the system and operation shall conform to the following:

7.4.2.1 The cathead shall be essentially free of rust, oil, or grease and have a diameter in the range of 6 to 10 in. (150 to 250 mm).

7.4.2.2 The cathead should be operated at a minimum speed of rotation of 100 RPM, or the approximate speed of rotation shall be reported on the boring log.

7.4.2.3 No more than 2¼ rope turns on the cathead may be used during the performance of the penetration test, as shown in Fig. 1.

NOTE 4—The operator should generally use either 1¾ or 2¼ rope turns, depending upon whether or not the rope comes off the top (1¾ turns) or the bottom (2¼ turns) of the cathead. It is generally known and accepted that 2¾ or more rope turns considerably impedes the fall of the hammer and should not be used to perform the test. The cathead rope should be maintained in a relatively dry, clean, and unfrayed condition.

7.4.2.4 For each hammer blow, a 30-in. (0.76-m) lift and drop shall be employed by the operator. The operation of pulling and throwing the rope shall be performed rhythmically without holding the rope at the top of the stroke.

7.5 Bring the sampler to the surface and open. Record the percent recovery or the length of sample recovered. Describe the soil samples recovered as to composition, color, stratification, and condition, then place one or more representative portions of the sample into sealable moisture-proof containers (jars) without ramming or distorting any apparent stratification. Seal each container to prevent evaporation of soil moisture. Affix labels to the containers bearing jo' designation, boring number, sample depth, and the blow count per 6-in. (0.15-m) increment. Protect the samples against extreme temperature changes. If there is a soil change within the sampler, make a jar for each stratum and note its location in the sampler barrel.

8. Report

8.1 Drilling information shall be recorded in the field and shall include the following:

8.1.1 Name and location of job,

8.1.2 Names of crew,

8.1.3 Type and make of drilling machine,

8.1.4 Weather conditions,

8.1.5 Date and time of start and finish of boring,

8.1.6 Boring number and location (station and coordinates, if available and applicable),

8.1.7 Surface elevation, if available,

8.1.8 Method of advancing and cleaning the boring,

8.1.9 Method of keeping boring open,

8.1.10 Depth of water surface and drilling depth at the time of a noted loss of drilling fluid, and time and date when reading or notation was made,

8.1.11 Location of strata changes,

8.1.12 Size of casing, depth of cased portion of boring,

8.1.13 Equipment and method of driving sampler,

8.1.14 Type sampler and length and inside diameter of barrel (note use of liners),

8.1.15 Size, type, and section length of the sampling rods, and

8.1.16 Remarks.

8.2 Data obtained for each sample shall be recorded in the field and shall include the following:

8.2.1 Sample depth and, if utilized, the sample number,

8.2.2 Description of soil,

8.2.3 Strata changes within sample,

8.2.4 Sampler penetration and recovery lengths, and

8.2.5 Number of blows per 6-in. (0.15-m) or partial increment.

9. Precision and Bias

9.1 *Precision*—A valid estimate of test precision has not been determined because it is too costly to conduct the necessary inter-laboratory (field) tests. Subcommittee D18.02 welcomes proposals to allow development of a valid precision statement.

9.2 *Bias*—Because there is no reference material for this test method, there can be no bias statement.

9.3 Variations in *N*-values of 100 % or more have been observed when using different standard penetration test apparatus and drillers for adjacent borings in the same soil formation. Current opinion, based on field experience, indicates that when using the same apparatus and driller, *N*-values in the same soil can be reproduced with a coefficient of variation of about 10 %.

9.4 The use of faulty equipment, such as an extremely massive or damaged anvil, a rusty cathead, a low speed cathead, an old, oily rope, or massive or poorly lubricated rope sheaves can significantly contribute to differences in *N*-values obtained between operator-drill rig systems.

9.5 The variability in N-values produced by different drill rigs and operators may be reduced by measuring that part of the hammer energy delivered into the drill rods from the sampler and adjusting N on the basis of comparative energies. A method for energy measurement and N-value adjustment is given in Test Method D 4633.

10. Keywords

10.1 blow count; in-situ test; penetration resistance; split-barrel sampling; standard penetration test

ATTACHMENT B

ASTM D1587-83

STANDARD PRACTICE FOR THIN-WALLED TUBE SAMPLING OF SOILS

Designation: D 1587 – 83

Standard Practice for
Thin-Walled Tube Sampling of Soils[1]

This standard is issued under the fixed designation D 1587; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This practice has been approved for use by agencies of the Department of Defense and for listing in the DOD Index of Specifications and Standards.

1. Scope

1.1 This practice covers a procedure for using a thin-walled metal tube to recover relatively undisturbed soil samples suitable for laboratory tests of structural properties. Thin-walled tubes used in piston, plug, or rotary-type samplers, such as the Denison or Pitcher, must comply with the portions of this practice which describe the thin-walled tubes (5.3).

NOTE 1—This practice does not apply to liners used within the above samplers.

2. Referenced Documents

2.1 *ASTM Standards:*

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[2]

D 3550 Practice for Ring-Lined Barrel Sampling of Soils[2]

D 4220 Practices for Preserving and Transporting Soil Samples[2]

3. Summary of Practice

3.1 A relatively undisturbed sample is obtained by pressing a thin-walled metal tube into the in-situ soil, removing the soil-filled tube, and sealing the ends to prevent the soil from being disturbed or losing moisture.

4. Significance and Use

4.1 This practice, or Practice D 3550, is used when it is necessary to obtain a relatively undisturbed specimen suitable for laboratory tests of structural properties or other tests that might be influenced by soil disturbance.

5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment may be used that provides a reasonably clean hole; that does not disturb the soil to be sampled; and that does not hinder the penetration of the thin-walled sampler. Open borehole diameter and the inside diameter of driven casing or hollow stem auger shall not exceed 3.5 times the outside diameter of the thin-walled tube.

5.2 *Sampler Insertion Equipment,* shall be adequate to provide a relatively rapid continuous penetration force. For hard formations it may be necessary, although not recommended, to drive the thin-walled tube sampler.

5.3 *Thin-Walled Tubes,* should be manufactured as shown in Fig. 1. They should have an outside diameter of 2 to 5 in. and be made of metal having adequate strength for use in the soil and formation intended. Tubes shall be clean and free of all surface irregularities including projecting weld seams.

5.3.1 *Length of Tubes*—See Table 1 and 6.4.

5.3.2 *Tolerances,* shall be within the limits shown in Table 2.

5.3.3 *Inside Clearance Ratio,* should be 1 % or as specified by the engineer or geologist for the soil and formation to be sampled. Generally, the inside clearance ratio used should increase with the increase in plasticity of the soil being sampled. See Fig. 1 for definition of inside clearance ratio.

5.3.4 *Corrosion Protection*—Corrosion, whether from galvanic or chemical reaction, can damage or destroy both the thin-walled tube and the sample. Severity of damage is a function of time as well as interaction between the sample and the tube. Thin-walled tubes should have some form of protective coating. Tubes which will contain samples for more than 72 h shall be coated. The type of coating to be used may vary depending upon the material to be sampled. Coatings may include a light coat of lubricating oil, lacquer, epoxy, Teflon, and others. Type of coating must be specified by the engineer or geologist if storage will exceed 72 h. Plating of the tubes or alternate base metals may be specified by the engineer or geologist.

5.4 *Sampler Head,* serves to couple the thin-walled tube to the insertion equipment and, together with the thin-walled tube, comprises the thin-walled tube sampler. The sampler head shall contain a suitable check valve and a venting area to the outside equal to or greater than the area through the check valve. Attachment of the head to the tube shall be concentric and coaxial to assure uniform application of force to the tube by the sampler insertion equipment.

6. Procedure

6.1 Clean out the borehole to sampling elevation using whatever method is preferred that will ensure the material to be sampled is not disturbed. If groundwater is encountered, maintain the liquid level in the borehole at or above ground water level during the sampling operation.

6.2 Bottom discharge bits are not permitted. Side discharge bits may be used, with caution. Jetting through an open-tube sampler to clean out the borehole to sampling elevation is not permitted. Remove loose material from the center of a casing or hollow stem auger as carefully as

[1] This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

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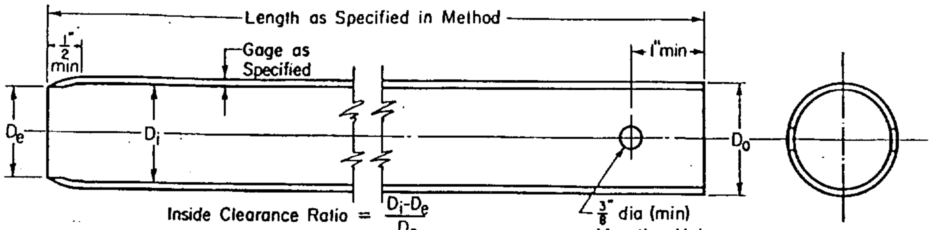
[2] *Annual Book of ASTM Standards,* Vol 04.08.



NOTE 1—Minimum of two mounting holes on opposite sides for 2 to 3½ in. sampler.
NOTE 2—Minimum of four mounting holes spaced at 90° for samplers 4 in. and larger.
NOTE 3—Tube held with hardened screws.
NOTE 4—Two-inch outside-diameter tubes are specified with an 18-gage wall thickness to comply with area ratio criteria accepted for "undisturbed samples." Users are advised that such tubing is difficult to locate and can be extremely expensive in small quantities. Sixteen-gage tubes are generally readily available.

Metric Equivalents

in.	mm
⅜	6.77
½	12.7
1	25.4
2	50.8
3½	88.9
4	101.6

FIG. 1 Thin-Walled Tube for Sampling

TABLE 1 Suitable Thin-Walled Steel Sample Tubes[A]

Outside diameter:			
in.	2	3	5
mm	50.8	76.2	127
Wall thickness:			
Bwg	18	16	11
in.	0.049	0.065	0.120
mm	1.24	1.65	3.05
Tube length:			
in.	36	36	54
m	0.91	0.91	1.45
Clearance ratio, %	1	1	1

[A] The three diameters recommended in Table 1 are indicated for purposes of standardization, and are not intended to indicate that sampling tubes of intermediate or larger diameters are not acceptable. Lengths of tubes shown are illustrative. Proper lengths to be determined as suited to field conditions.

TABLE 2 Dimensional Tolerances for Thin-Walled Tubes

	Nominal Tube Diameters from Table 1[A] Tolerances, in.		
Size Outside Diameter	2	3	5
Outside diameter	+0.007 −0.000	+0.010 −0.000	+0.015 −0.000
Inside diameter	+0.000 −0.007	+0.000 −0.010	+0.000 −0.015
Wall thickness	±0.007	±0.010	±0.015
Ovality	0.015	0.020	0.030
Straightness	0.030/ft	0.030/ft	0.030/ft

[A] Intermediate or larger diameters should be proportional. Tolerances shown are essentially standard commercial manufacturing tolerances for seamless steel mechanical tubing. Specify only two of the first three tolerances; that is, O.D. and I.D., or O.D. and Wall, or I.D. and Wall.

possible to avoid disturbance of the material to be sampled.

NOTE 2—Roller bits are available in downward-jetting and diffused-jet configurations. Downward-jetting configuration rock bits are not acceptable. Diffuse-jet configurations are generally acceptable.

6.3 Place the sample tube so that its bottom rests on the bottom of the hole. Advance the sampler without rotation by a continuous relatively rapid motion.

6.4 Determine the length of advance by the resistance and condition of the formation, but the length shall never exceed 5 to 10 diameters of the tube in sands and 10 to 15 diameters of the tube in clays.

NOTE 3—Weight of sample, laboratory handling capabilities, transportation problems, and commercial availability of tubes will generally limit maximum practical lengths to those shown in Table 1.

6.5 When the formation is too hard for push-type insertion, the tube may be driven or Practice D 3550 may be used. Other methods, as directed by the engineer or geologist, may be used. If driving methods are used, the data regarding weight and fall of the hammer and penetration achieved must be shown in the report. Additionally, that tube must be prominently labeled a "driven sample."

6.6 In no case shall a length of advance be greater than the sample-tube length minus an allowance for the sampler head and a minimum of 3 in. for sludge-end cuttings.

NOTE 4—The tube may be rotated to shear bottom of the sample after pressing is complete.

6.7 Withdraw the sampler from the formation as carefully as possible in order to minimize disturbance of the sample.

7. Preparation for Shipment

7.1 Upon removal of the tube, measure the length of sample in the tube. Remove the disturbed material in the upper end of the tube and measure the length again. Seal the upper end of the tube. Remove at least 1 in. of material from the lower end of the tube. Use this material for soil description in accordance with Practice D 2488. Measure the overall sample length. Seal the lower end of the tube. Alternatively, after measurement, the tube may be sealed without removal of soil from the ends of the tube if so directed by the engineer or geologist.

NOTE 5—Field extrusion and packaging of extruded samples under the specific direction of a geotechnical engineer or geologist is permitted.
NOTE 6—Tubes sealed over the ends as opposed to those sealed with expanding packers should contain end padding in end voids in order to prevent drainage or movement of the sample within the tube.

7.2 Prepare and immediately affix labels or apply markings as necessary to identify the sample. Assure that the markings or labels are adequate to survive transportation and storage.

8. Report

8.1 The appropriate information is required as follows:

8.1.1 Name and location of the project,

8.1.2 Boring number and precise location on project,

8.1.3 Surface elevation or reference to a datum,

8.1.4 Date and time of boring—start and finish,

8.1.5 Depth to top of sample and number of sample,

8.1.6 Description of sampler: size, type of metal, type of coating,

8.1.7 Method of sampler insertion: push or drive,

8.1.8 Method of drilling, size of hole, casing, and drilling fluid used,

8.1.9 Depth to groundwater level: date and time measured,

8.1.10 Any possible current or tidal effect on water level,

8.1.11 Soil description in accordance with Practice D 2488,

8.1.12 Length of sampler advance, and

8.1.13 Recovery: length of sample obtained.

9. Precision and Bias

9.1 This practice does not produce numerical data; therefore, a precision and bias statement is not applicable.

ATTACHMENT C

ASTM D2113-83 (1987)

STANDARD PRACTICE FOR DIAMOND CORE DRILLING FOR SITE INVESTIGATION

Designation: D 2113 – 83 (Reapproved 1987)

Standard Practice for Diamond Core Drilling for Site Investigation[1]

This standard is issued under the fixed designation D 2113; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice describes equipment and procedures for diamond core drilling to secure core samples of rock and some soils that are too hard to sample by soil-sampling methods. This method is described in the context of obtaining data for foundation design and geotechnical engineering purposes rather than for mineral and mining exploration.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1586 Method for Penetration Test and Split-Barrel Sampling of Soils[2]

D 1587 Practice for Thin-Walled Tube Sampling of Soils[2]

D 3550 Practice for Ring-Lined Barrel Sampling of Soils[2]

3. Significance and Use

3.1 This practice is used to obtain core specimens of superior quality that reflect the in-situ conditions of the material and structure and which are suitable for standard physical-properties tests and structural-integrity determination.

4. Apparatus

4.1 *Drilling Machine,* capable of providing rotation, feed, and retraction by hydraulic or mechanical means to the drill rods.

4.2 *Fluid Pump or Air Compressor,* capable of delivering sufficient volume and pressure for the diameter and depth of hole to be drilled.

4.3 *Core barrels,* as required:

4.3.1 *Single Tube Type, WG Design,* consisting of a hollow steel tube, with a head at one end threaded for drill rod, and a threaded connection for a reaming shell and core bit at the other end. A core lifter, or retainer located within the core bit is normal, but may be omitted at the discretion of the geologist or engineer.

4.3.2 *Double Tube, Swivel-Type, WG Design*—An assembly of two concentric steel tubes joined and supported at the upper end by means of a ball or roller-bearing swivel arranged to permit rotation of the outer tube without causing rotation of the inner tube. The upper end of the outer tube, or removable head, is threaded for drill rod. A threaded connection is provided on the lower end of the outer tube for a reaming shell and core bit. A core lifter located within the core bit is normal but may be omitted at the discretion of the geologist or engineer.

4.3.3 *Double-Tube, Swivel-Type, WT Design,* is essentially the same as the double tube, swivel-type, WG design, except that the WT design has thinner tube walls, a reduced annular area between the tubes, and takes a larger core from the same diameter bore hole. The core lifter is located within the core bit.

4.3.4 *Double Tube, Swivel Type, WM Design,* is similar to the double tube, swivel-type, WG design, except that the inner tube is threaded at its lower end to receive a core lifter case that effectively extends the inner tube well into the core bit, thus minimizing exposure of the core to the drilling fluid. A core lifter is contained within the core lifter case on the inner tube.

4.3.5 *Double Tube Swivel-Type, Large-Diameter Design,* is similar to the double tube, swivel-type, WM design, with the addition of a ball valve, to control fluid flow, in all three available sizes and the addition of a sludge barrel, to catch heavy cuttings, on the two larger sizes. The large-diameter design double tube, swivel-type, core barrels are available in three core per hole sizes as follows: 2¾ in. (69.85 mm) by 3⅞ in. (98.43 mm), 4 in. (101.6 mm) by 5½ in. (139.7 mm), and 6 in. (152.4 mm) by 7¾ in. (196.85 mm). Their use is generally reserved for very detailed investigative work or where other methods do not yield adequate recovery.

4.3.6 *Double Tube, Swivel-Type, Retrievable Inner-Tube Method,* in which the core-laden inner-tube assembly is retrieved to the surface and an empty inner-tube assembly returned to the face of the borehole through the matching large-bore drill rods without need for withdrawal and replacement of the drill rods in the borehole. The inner-tube assembly consists of an inner tube with removable core lifter case and core lifter at one end and a removable inner-tube head, swivel bearing, suspension adjustment, and latching device with release mechanism on the opposite end. The inner-tube latching device locks into a complementary recess in the wall of the outer tube such that the outer tube may be rotated without causing rotation of the inner tube and such that the latch may be actuated and the inner-tube assembly transported by appropriate surface control. The outer tube is threaded for the matching, large-bore drill rod and internally configured to receive the inner-tube latching device at one end and threaded for a reaming shell and bit, or bit only, at the other end.

4.4 *Longitudinally Split Inner Tubes*—As opposed to conventional cylindrical inner tubes, allow inspection of, and access to, the core by simply removing one of the two halves. They are not standardized but are available for most core barrels including many of the retrievable inner-tube types.

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[1] This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

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[2] *Annual Book of ASTM Standards,* Vol 04.08.

4.5 *Core Bits*—Core bits shall be surface set with diamonds, impregnated with small diamond particles, inserted with tungsten carbide slugs, or strips, hard-faced with various hard surfacing materials or furnished in saw-tooth form, all as appropriate to the formation being cored and with concurrence of the geologist or engineer. Bit matrix material, crown shape, water-way type, location and number of water ways, diamond size and carat weight, and bit facing materials shall be for general purpose use unless otherwise approved by the geologist or engineer. Nominal size of some bits is shown in Table 1.

NOTE 1—Size designation (letter symbols) used throughout the text and in Tables 1, 2, and 3 are those standardized by the Diamond Core Drill Manufacturers' Assoc. (DCDMA). Inch dimensions in the tables have been rounded to the nearest hundredth of an inch.

4.6 *Reaming Shells,* shall be surface set with diamonds, impregnated with small diamond particles, inserted with tungsten carbide strips or slugs, hard faced with various types of hard surfacing materials, or furnished blank, all as appropriate to the formation being cored.

4.7 *Core Lifters*—Core lifters of the split-ring type, either plain or hard-faced, shall be furnished and maintained, along with core-lifter cases or inner-tube extensions or inner-tube shoes, in good condition. Basket or finger-type lifters, together with any necessary adapters, shall be on the job and available for use with each core barrel if so directed by the geologist or engineer.

4.8 *Casings:*

4.8.1 *Drive Pipe or Drive Casing,* shall be standard weight (schedule 40), extra-heavy (schedule 80), double extra-heavy (schedule 160) pipe or W-design flush-joint casing as required by the nature of the overburden or the placement method. Drive pipe or W-design casing shall be of sufficient diameter to pass the largest core barrel to be used, and it shall be driven to bed rock or to firm seating at an elevation below water-sensitive formation. A hardened drive shoe is to be used as a cutting edge and thread protection device on the bottom of the drive pipe or casing. The drive shoe inside diameter shall be large enough to pass the tools intended for use, and the shoe and pipe or casing shall be free from burrs or obstructions.

4.8.2 *Casing*—When necessary to case through formations already penetrated by the borehole or when no drive casing has been set, auxiliary casing shall be provided to fit inside the borehole to allow use of the next smaller core barrel. Standard sizes of telescoping casing are shown in Table 2. Casing bits have an obstruction in their interior and will not pass the next smaller casing size. Use a casing shoe if additional telescoping is anticipated.

4.8.3 *Casing Liner*—Plastic pipe or sheet-metal pipe may be used to line an existing large-diameter casing. Liners, so used, should not be driven, and care should be taken to maintain true alignment throughout the length of the liner.

4.8.4 *Hollow Stem Auger*—Hollow stem auger may be used as casing for coring.

4.9 *Drill Rods:*

4.9.1 *Drill Rods of Tubular Steel Construction* are normally used to transmit feed, rotation, and retraction forces from the drilling machine to the core barrel. Drill-rod sizes that are presently standardized are shown in Table 3.

4.9.2 Large bore drill rods used with retrievable inner-tube core barrels are not standardized. Drill rods used with retrievable inner-tube core barrels should be those manufactured by the core-barrel manufacturer specifically for the core barrel.

4.9.3 *Composite Drill Rods* are specifically constructed from two or more materials intended to provide specific properties such as light weight or electrical nonconductivity.

4.9.4 *Nonmagnetic Drill Rods* are manufactured of nonferrous materials such as aluminum or brass and are used primarily for hole survey work. Some nonmagnetic rods have left-hand threads in order to further their value in survey work. No standard exists for nonmagnetic rods.

4.10 *Auxiliary Equipment,* shall be furnished as required by the work and shall include: roller rock bits, drag bits, chopping bits, boulder busters, fishtail bits, pipe wrenches, core barrel wrenches, lubrication equipment, core boxes, and marking devices. Other recommended equipment includes:

TABLE 1 Core Bit Sizes

Size Designation	Outside Diameter		Inside Diameter	
	in.	mm	in.	mm
RWT	1.16	29.5	0.375	18.7
EWT	1.47	37.3	0.905	22.9
EWG, EWM	1.47	37.3	0.845	21.4
AWT	1.88	47.6	1.281	32.5
AWG, AWM	1.88	47.6	1.185	30.0
BWT	2.35	59.5	1.750	44.6
BWG, BWM	2.35	59.5	1.655	42.0
NWT	2.97	75.3	2.313	58.7
NWG, NWM	2.97	75.3	2.155	54.7
2¾ × 3⅞	3.84	97.5	2.69	68.3
HWT	3.89	98.8	3.187	80.9
HWG, . . .	3.89	98.8	3.000	76.2
4 × 5½	5.44	138.0	3.97	100.8
6 × 7¾	7.66	194.4	5.97	151.6

TABLE 2 Casing Sizes

Size Designation	Outside Diameter		Inside Diameter		Threads per in.	Will Fit Hole Drilled with Core Bit Size
	in.	mm	in.	mm		
RW	1.144	36.5	1.19	30.1	5	EWT, EWG, EWM
EW	1.81	46.0	1.50	38.1	4	AWT, AWG, AWM
AW	2.25	57.1	1.91	48.4	4	BWT, BWG, BWM
BW	2.88	73.0	2.38	60.3	4	NWT, NWG, NWM
NW	3.50	88.9	3.00	76.2	4	HWT, HWG
HW	4.50	114.3	4.00	101.6	4	4 × 5½
PW	5.50	139.7	5.00	127.0	3	6 × 7¾
SW	6.63	168.2	6.00	152.4	3	6 × 7¾
UW	7.63	193.6	7.00	177.8	2	. . .
ZW	8.63	219.0	8.00	203.2	2	. . .

TABLE 3 Drill Rods

Size Designation	Rod and Coupling Outside Diameter		Rod Inside Diameter		Coupling Bore, Threads		
	in.	mm	in.	mm	in.	mm	per in.
RW	1.09	27.7	0.72	18.2	0.41	10.3	4
EW	1.38	34.9	1.00	25.4	0.44	11.1	3
AW	1.72	43.6	1.34	34.1	0.63	15.8	3
BW	2.13	53.9	1.75	44.4	0.75	19.0	3
NW	2.63	66.6	2.25	57.1	1.38	34.9	3
HW	3.50	88.9	3.06	77.7	2.38	60.3	3

core splitter, rod wicking, pump-out tools or extruders, and hand sieve or strainer.

5. Transportation and Storage of Core Containers

5.1 *Core Boxes*, shall be constructed of wood or other durable material for the protection and storage of cores while enroute from the drill site to the laboratory or other processing point. All core boxes shall be provided with longitudinal separators and recovered cores shall be laid out as a book would read, from left to right and top to bottom, within the longitudinal separators. Spacer blocks or plugs shall be marked and inserted into the core column within the separators to indicate the beginning of each coring run. The beginning point of storage in each core box is the upper left-hand corner. The upper left-hand corner of a hinged core box is the left corner when the hinge is on the far side of the box and the box is right-side up. All hinged core boxes must be permanently marked on the outside to indicate the top and the bottom. All other core boxes must be permanently marked on the outside to indicate the top and the bottom and additionally, must be permanently marked internally to indicate the upper-left corner of the bottom with the letters UL or a splotch of red paint not less than 1 in.[2] Lid or cover fitting(s) for core boxes must be of such quality as to ensure against mix up of the core in the event of impact or upsetting of the core box during transportation.

5.2 Transportation of cores from the drill site to the laboratory or other processing point shall be in durable core boxes so padded or suspended as to be isolated from shock or impact transmitted to the transporter by rough terrain or careless operation.

5.3 Storage of cores, after initial testing or inspection at the laboratory or other processing point, may be in cardboard or similar less costly boxes provided all layout and marking requirements as specified in 5.1 are followed. Additional spacer blocks or plugs shall be added if necessary at time of storage to explain missing core. Cores shall be stored for a period of time specified by the engineer but should not normally be discarded prior to completion of the project for which they were taken.

6. Procedure

6.1 Use core-drilling procedures when formations are encountered that are too hard to be sampled by soil-sampling methods. A 1-in. (25.4-mm) or less penetration for 50 blows in accordance with Method D 1586 or other criteria established by the geologist or engineer, shall indicate that soil-sampling methods are not applicable.

6.1.1 Seat the casing on bedrock or in a firm formation to prevent raveling of the borehole and to prevent loss of drilling fluid. Level the surface of the rock or hard formation at the bottom of the casing when necessary, using the appropriate bits. Casing may be omitted if the borehole will stand open without the casing.

6.1.2 Begin the core drilling using an N-size double-tube swivel-type core barrel or other size or type approved by the engineer. Continue core drilling until core blockage occurs or until the net length of the core barrel has been drilled in. Remove the core barrel from the hole and disassemble it as necessary to remove the core. Reassemble the core barrel and return it to the hole. Resume coring.

6.1.3 Place the recovered core in the core box with the upper (surface) end of the core at the upper-left corner of the core box as described in 5.1. Continue boxing core with appropriate markings, spacers, and blocks as described in 5.1. Wrap soft or friable cores or those which change materially upon drying in plastic film or seal in wax, or both, when such treatment is required by the engineer. Use spacer blocks or slugs properly marked to indicate any noticeable gap in recovered core which might indicate a change or void in the formation. Fit fracture, bedded, or jointed pieces of core together as they naturally occurred.

6.1.4 Stop the core drilling when soft materials are encountered that produce less than 50 % recovery. If necessary, secure samples of soft materials in accordance with the procedures described in Method D 1586, Practice D 1587, or Practice D 3550, or by any other method acceptable to the geologist or engineer. Resume diamond core drilling when refusal materials as described in 6.1 are again encountered.

6.2 Subsurface structure, including the dip of strata, the occurrence of seams, fissures, cavities, and broken areas are among the most important items to be detected and described. Take special care to obtain and record information about these features. If conditions prevent the continued advance of the core drilling, the hole should be cemented and redrilled, or reamed and cased, or cased and advanced with the next smaller-size core barrel, as required by the geologist or engineer.

6.3 Drilling mud or grouting techniques must be approved by the geologist or engineer prior to their use in the borehole.

6.4 *Compatibility of Equipment:*

6.4.1 Whenever possible, core barrels and drill rods should be selected from the same letter-size designation to ensure maximum efficiency. See Tables 1 and 3.

6.4.2 Never use a combination of pump, drill rod, and core barrel that yields a clear-water up-hole velocity of less than 120 ft/min.

6.4.3 Never use a combination of air compressor, drill rod, and core barrel that yields a clear-air up-hole velocity of less than 3000 ft/min.

7. Boring Log

7.1 The boring log shall include the following:

7.1.1 Project identification, boring number, location, date boring began, date boring completed, and driller's name.

7.1.2 Elevation of the ground surface.

7.1.3 Elevation of or depth to ground water and raising or lowering of level including the dates and the times measured.

7.1.4 Elevations or depths at which drilling fluid return was lost.

7.1.5 Size, type, and design of core barrel used. Size, type, and set of core bit and reaming shell used. Size, type, and length of all casing used. Description of any movements of the casing.

7.1.6 Length of each core run and the length or percentage, or both, of the core recovered.

7.1.7 Geologist's or engineer's description of the formation recovered in each run.

7.1.8 Driller's description, if no engineer or geologist is present, of the formation recovered in each run.

7.1.9 Subsurface structure description, including dip of strata and jointing, cavities, fissures, and any other observations made by the geologist or engineer that could yield information regarding the formation.

7.1.10 Depth, thickness, and apparent nature of the filling of each cavity or soft seam encountered, including opinions gained from the feel or appearance of the inside of the inner tube when core is lost. Record opinions as such.

7.1.11 Any change in the character of the drilling fluid or drilling fluid return.

7.1.12 Tidal and current information when the borehole is sufficiently close to a body of water to be affected.

7.1.13 Drilling time in minutes per foot and bit pressure in pound-force per square inch gage when applicable.

7.1.14 Notations of character of drilling, that is, soft, slow, easy, smooth, etc.

8. Precision and Bias

8.1 This practice does not produce numerical data; therefore, a precision and bias statement is not applicable.

NOTE 2—Inclusion of the following tables and use of letter symbols in the foregoing text is not intended to limit the practice to use of DCDMA tools. The table and text references are included as a convenience to the user since the vast majority of tools in use do meet DCDMA dimensional standards. Similar equipment of approximately equal size on the metric standard system is acceptable unless otherwise stipulated by the engineer or geologist.

APPENDIX B

Test Pit and Trench Excavation

APPENDIX C

Monitoring Well Installation

MONITORING WELL INSTALLATION
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1.0 PURPOSE

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- 5.2 Surface Completion
- 5.3 Well Development
- 5.4 Contaminated Materials Handling
- 5.5 Well Construction Logs

6.0 QUALITY ASSURANCE RECORDS

7.0 REFERENCES

MONITORING WELL INSTALLATION

1.0 PURPOSE

The purpose of this procedure is to provide general guidance and reference material regarding the installation of monitoring wells at various sites.

2.0 SCOPE

This SOP describes the methods of installing a groundwater monitoring well, and creating a Monitoring Well Installation Record. This SOP does not discuss drilling, soil sampling, borehole logging or related activities. These other activities are discussed in SOPs F102 and F101 entitled Soil and Rock Sample Acquisition, and Borehole and Sample Logging, respectively.

3.0 DEFINITIONS

Monitoring Well - A monitoring well is a well which is properly screened, cased, and sealed to intercept a discrete zone of the subsurface, and is capable of providing a groundwater level and sample representative of the zone being monitored.

Piezometer - A piezometer is a pipe or tube inserted into an aquifer or other water-bearing zone, open to water flow at the bottom, open to the atmosphere at the top, and used to measure water level elevations. Piezometers are not used for the collection of groundwater quality samples or aquifer characteristic data other than water level elevations.

4.0 RESPONSIBILITIES

Project Manager - It is the responsibility of the Project Manager to ensure that field personnel installing monitoring wells are familiar with these procedures. The Project Manager also is responsible for ensuring that all appropriate documents (e.g., test boring logs, monitoring well construction logs, etc.) have been correctly and completely filled out by the drilling inspector.

Field Team Leader - The Field Team Leader is responsible for the overall supervision of all drilling, boring and well installation activities, and for ensuring that the well is completely and correctly installed and logged. The Field Team Leader also is responsible for ensuring that all drilling inspectors have been briefed on these procedures.

Drilling Inspector (Site Geologist) - The Drilling Inspector or Site Geologist is responsible for the direct supervision of drilling and well installation activities. It is the Drilling Inspector's responsibility to log each boring and details of the well installation, document subsurface conditions, complete the appropriate forms, and supervise the drilling crew (or drilling supervisor).

5.0 PROCEDURES

The objectives for the use of each monitoring well and of the entire array of wells must be clearly defined before the monitoring system is designed. Within the monitoring system, different monitoring wells may serve different purposes and, therefore, may require different types of construction. During all phases of the well design (both office and field), attention must be given to clearly documenting the basis for design decisions, the details of well construction, and the materials used.

The objectives for installing monitoring wells may include:

- Determining groundwater flow directions and velocities.
- Sampling or monitoring for groundwater contamination.
- Determining aquifer characteristics (e.g., hydraulic conductivity).
- Performing site remediation via injection or recovery.

In cases where only the groundwater flow direction or velocity needs to be determined, cluster piezometers or wells (i.e., wells completed to different depths in different boreholes at one data collection station) may be used. For groundwater quality monitoring or aquifer characteristic determination, monitoring wells or cluster wells should be used.

Siting of monitoring wells shall be performed after a preliminary estimation of groundwater flow direction. Typically, site visits, topographic mapping, regional/local hydrogeologic information, previously installed piezometers or monitoring wells, or information supplied by local drilling companies will provide information for siting wells. Flexibility should be maintained, so that well locations may be modified during the field investigation to account for site conditions. The horizontal and vertical locations of all monitoring wells shall be determined through a site survey upon completion of well installation.

Guidelines for Navy underground storage tank (UST) monitoring well construction are given in Attachment A.

5.1 Well Installation

For purposes of this SOP, the methods discussed in this section are applicable to shallow, small diameter monitoring wells. Project-specific modifications to these methods shall be documented in the Sampling and Analysis Plan. These modifications may include larger diameter shallow wells, extraction wells, deep monitoring wells requiring surface casing and other specially constructed well types. Typical shallow monitoring well construction details are shown in Figures A-1 and A-2 in Attachment A for wells with flush-mounted and stick-up wells, respectively.

Note that these procedures discuss well installation using a PVC screen and riser pipe. Other materials such as stainless steel or Teflon are also available. However, PVC generally is much less expensive and easier to work with than either stainless steel or Teflon. A disadvantage to using PVC is the potential for degradation of the materials, or release (leaching) of constituents into the groundwater. Because of these concerns, justification for using PVC must be developed on a project-specific basis. The checklist shown in Attachment B provides a format for developing this justification.

Upon completion of each boring (refer to SOP F101 and F102 for Borehole and Sample Logging, and Soil and Rock Sample Acquisition, respectively), monitoring wells will usually be constructed using either two-inch or four-inch inside diameter (I.D.) screen and riser. Schedule 40 PVC, threaded, flush-joint casings with a continuous #10 slot (0.010-inch), threaded, flush-joint PVC screen. If wells are to be constructed over 100 feet in length, or in high traffic areas, or under other unusual conditions, Schedule 80 PVC may be used because of its greater strength.

An appropriate length of well screen shall be installed in each boring. The length of screen typically varies from one to 20 feet depending on site-specific conditions. For UST applications, the screen should be installed such that at least two-feet of screen is above the water table and the remainder of the screen extends below the water surface. Should very shallow water table conditions be encountered, the screened interval in both the saturated and unsaturated zones may be reduced to ensure an adequate well seal above the screened interval. If this situation is expected, it should be addressed in the project plans, as necessary. A six-inch section of PVC casing may be placed at the bottom of each screen to act as a settling cup for fines which may pass through the filter pack and screen.

Other applications may call for different screen placement depending on the zone to be monitored and the expected contaminants. For example, monitoring for dense non-aqueous phase liquids *(DNAPLS)* may require placing the screened interval in a "sump" at the base of the aquifer. Depending on the purpose of the monitoring well, the riser pipe may extend from the top of the screened interval to either six inches below the ground surface (for flush-mounted wells) to between one and two feet above the ground surface for wells completed with stick-up.

The annular space around the screen is to be successfully backfilled with a well graded quartz-sand, sodium bentonite and cement/bentonite grout as the hollow-stem augers are being withdrawn from the borehole. The sand size used in well construction will be appropriate for the formation monitored by the well. Sand shall be placed, preferably via tremie pipe, from the bottom of the boring to approximately two feet above the top of the screened interval. A lesser distance above the top of the screened interval may be packed with sand if the well is very shallow to allow for placement of sealing materials.

A sodium bentonite seal at least one-foot thick (but no more than three-feet thick) shall be place above the sand pack. The bentonite shall be allowed to hydrate for at least 20 minutes before further completion of the well. Distilled water will be added to the well to hydrate the bentonite, if necessary.

The annular space above the bentonite seal will be backfilled with a cement/bentonite and grout consisting of three to four percent bentonite powder (by dry weight) and seven gallons of potable water per 94 pound bag of portland cement. The grout mixture shall be specified in the project plans. The grout will be tremied into the annular space, preferably with a side-discharge tremie pipe, into annular spaces greater than ten feet high. If the annular space is less than ten feet high, the grout may be poured directly into the annular space.

The depth intervals of all backfill materials shall be measured with a weighted measuring tape to the nearest 0.1 foot and recorded on the Field Monitoring Well Construction Record or in a field logbook.

5.2 Surface Completion

There are several methods for surface completion of monitoring wells. Two such methods are discussed below.

The first method considers wells completed with stick-up. The aboveground section of the PVC riser pipe will be protected by installation of a four or six-inch diameter, five-foot long steel casing with locking cap and lock into the cement grout. The bottom of the surface casing will be placed at a minimum of 2-1/2, but not more than 3-1/2 feet below the ground surface, as space permits, with an inverted taper to protect the casing from frost heaving. For very shallow wells, a steel casing of less than five-feet in length may be used, as space permits. The protective steel casing shall not fully penetrate the bentonite seal.

The top of each well will be protected with the installation of three, three-inch diameter, five-foot long steel pipes for UST projects (four for IR projects) and have a concrete apron. The steel pipes shall be embedded to a minimum depth of 2.5-feet in 3,000 psi concrete. Each pipe shall also be filled with concrete. A concrete apron approximately five-feet by five-feet by 0.5-feet thick shall be placed at the same time the pipes are installed. The steel pipes shall be painted with day-glo yellow paint, or equivalent.

The second method considers flush-mounted wells, typically installed in traffic areas. The monitoring well shall be completed at the surface using a "flush" mount type cover. If the well is installed through a paved or concrete surface, the annular space shall be grouted to a depth of at least 2.5-feet and the well shall be finished with a concrete collar. If the well has not been installed through a paved or concrete surface, the well shall be completed by construction of a five-foot by five-foot by 0.5-foot thick apron made of 3,000 psi concrete. The concrete shall be crowned to meet the finished grade of the surrounding pavement, as required. If appropriate, the vault around the buried wellhead will have a water drain to the surrounding soil and a watertight cover.

All monitoring wells shall be labeled by metal stamping on the exterior of the protective steel casing locking cap, and also by labeling on the exterior of the steel casing or manhole cover. For underground storage tank applications, the labeling shall consist of the letters UGW (UST Groundwater), and a number specific to each well. A sign reading "Not For Potable Use or Disposal" also shall be firmly attached to each well. Alternately, well identification information may be stamped on a metal plate and attached to the well protective steel casing or embedded in the concrete apron, if appropriate.

5.3 Well Development

There are two stages of well development, initial and sampling. Sampling development is described in SOP F104, Groundwater Sample Acquisition. Initial development takes place after the completion materials have stabilized, as the last part of well construction.

The purposes of the initial development are to stabilize and increase the permeability of the filter pack around the well screen, to restore the permeability of the formation which may have been reduced by the drilling operations, and to remove fine-grained materials that may have entered the well or filter pack during installation. The selection of the well development method typically is based on drilling methods, well construction and installation details, and the characteristics of the formation. Any equipment that is introduced into the well during development shall be decontaminated in accordance with the SOP F501, entitled "Decontamination of Drilling Rigs, Heavy Equipment and Monitoring Well Materials." A detailed discussion of well development is provided in Driscoll, 1986.

Well development shall not be initiated until a minimum of 24 hours has elapsed subsequent to well completion. This time period will allow the cement grout to set. Wells typically are developed using bailers, low-yield pumping, or surging with a surge block or air. The appropriate method shall be specified in the project plans.

All wells shall be developed until well water runs relatively clear of fine-grained materials. Note that the water in some wells does not clear with continued development. Typical limits placed on well development may include any one of the following:

- Clarity of water based on visual determination.

- A maximum time period (typically one hour for shallow wells 10 to 30 feet deep).
- A maximum borehole volume (typically three to five borehole volumes).
- Stability of specific conductance and temperature measurements (typically less than 10 percent change between three successive measurements).
- Clarity based on turbidity measurements (typically less than 50 NTU).

In addition, a volume equal to any water added during drilling will be removed above and beyond the requirement specified above.

Well development limits shall be specified in project-specific plans. A record of the well development (Figure A-3 in Attachment A) also shall be completed to document the development process.

Usually, a minimum period of two weeks should elapse between the end of initial development and the first sampling event for a well. This equilibration period allows groundwater unaffected by the installation of the well to occupy the vicinity of the screened interval. However, this stabilization period may be adjusted based upon project-specific requirements.

5.4 Contaminated Materials Handling

SOP F504, entitled "Handling of Site Investigation Derived Waste~~s~~," discusses the procedures to be used for the handling of auger cuttings, decontamination water, steam pad water, and development and purge water. Specific handling procedures should be delineated in the project plans. In general, all site investigation generated wastes shall be containerized unless otherwise specified by LANTDIV. The disposition of these wastes shall be determined after receipt of the appropriate analytical results.

5.5 Well Construction Logs

Field Well Construction Logs shall be completed by the Drilling Inspector for each monitoring well installed. These logs preferably shall be completed as the well is being constructed. However, due to space limitations on this form it may be more practical to record well installation information in the field logbook and later transfer it to the Well Construction Log.

If well construction information is recorded in the field logbook, it must be transferred to the appropriate form within five days, or prior to demobilization from the field.

Field Well Construction Logs (in Attachment C), shall include not only well construction information, but also information pertaining to the amount of materials used for construction. Some of the following items shall be recorded on the Field Well Construction Log, or in the field logbook, as appropriate:

- Project name and location.
- CTO number.
- Date and weather.
- Well identification designation.
- Drilling company and driller.
- Top of casing elevation (information collected after the site survey).
- Pay items including amount of screen and riser pipe used, amounts of cement, bentonite and sand used, and other well construction items.
- Well casing and borehole diameters.
- Elevations of (or depth to) top of steel casing, bottom of well, top of filter pack, top of bentonite seal, top of screen.

The information on the Field Well Construction Log will be used to generate a final Well Construction Log which combines the Field Boring and Well Construction Logs into one package. An example of all three documents is presented in Attachment C.

6.0 QUALITY ASSURANCE RECORDS

The Field Well Construction Record is the principle quality assurance record generated from well installation activities. Additionally, a Field Well Development Record shall also be completed, as well as pertinent comments in the field logbook.

7.0 REFERENCES

1. Driscoll, Fletcher, G. Groundwater and Wells , Johnson division. St. Paul, Minnesota. 2nd ed. 1986.

2. Roscoe Moss Company. Handbook of Ground Water Development. John Wiley & Sons. New York. 1990.

3. USEPA. RCRA Ground-Water Monitoring Technical Enforcement Guidance Document. September, 1986.

ATTACHMENT A

MONITORING WELL CONSTRUCTION AND FIELD OPERATIONS

ATTACHMENT A

UST MONITORING WELL CONSTRUCTION AND FIELD OPERATIONS

SPECIFICATIONS

Well permits required by state agencies are the responsibility of the contractor. All monitoring wells will be installed in accordance with Navy UST monitoring well specifications. The wells will be constructed of either a 2-inch or 4-inch inside diameter (I.D.) flush joint threaded PVC well screen and riser casing depending on conditions encountered during borehole completion.

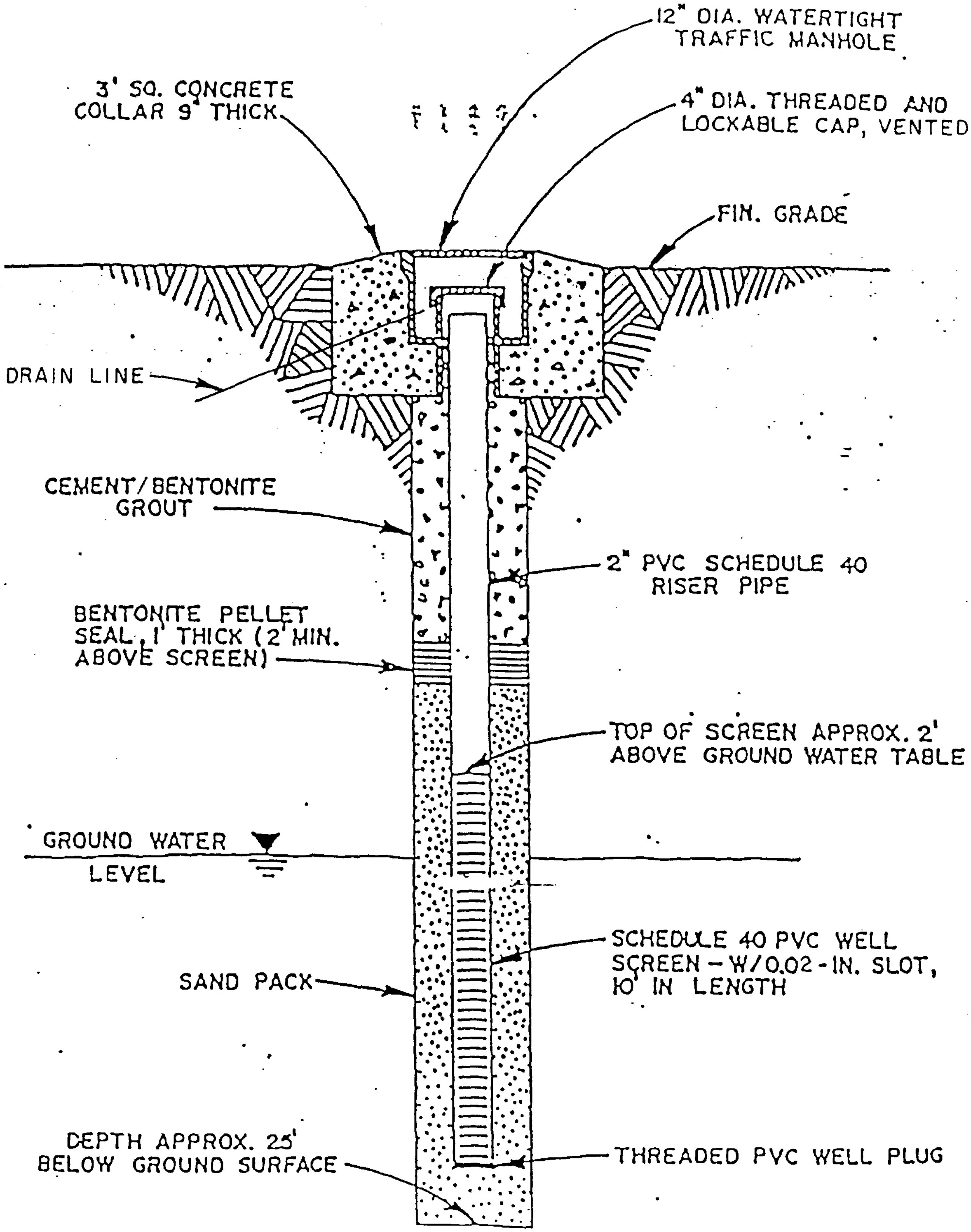
DRILLING

During the drilling program, boreholes will be advanced using conventional hollow-stem auger drilling methods. If it is the opinion of the contractor that air or mud rotary drill methods are necessary, approval must be obtained from the Engineer-in-Charge (EIC). Presentation of justification for a boring method change shall be presented prior to drilling.

Well construction details are shown in Figures A-1 and A-2. A drill mounted on an All-Terrain-Vehicle (ATV) may be required for access to remote areas. Each rig will use necessary tools, supplies and equipment supplied by the contractor to drill each site. Drill crews should consist of an experienced driller and a driller assistant for work on each rig. A geologist, experienced in hazardous waste site investigations, shall be on site to monitor the drillers efforts and for air monitoring/safety control. Additional subcontractor personnel may be needed to transport water to the rigs, clean tools, assist in the installation of the security and marker pipes, construct the concrete aprons/collars and develop the wells. A potable water source on base will be designated by the Government.

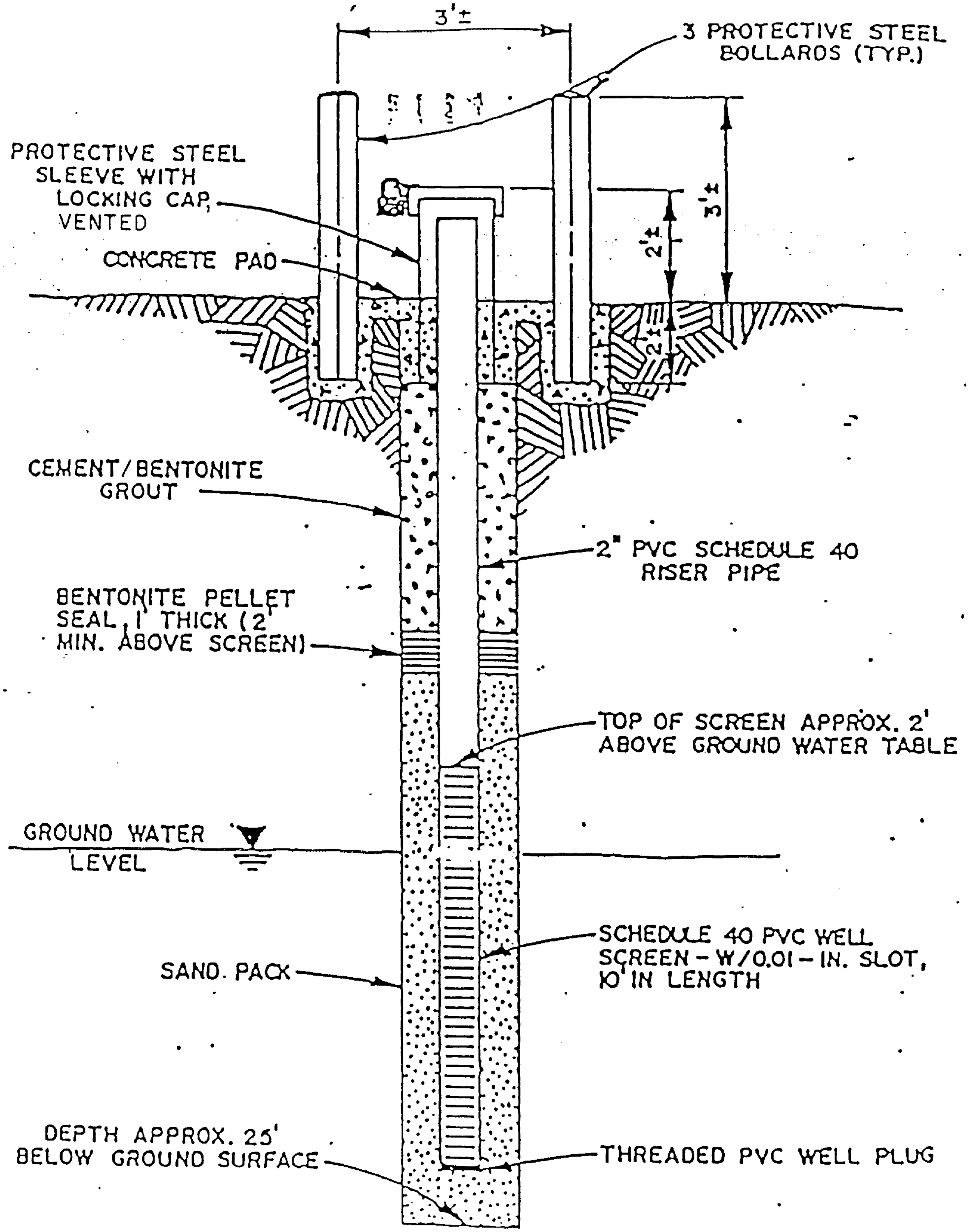
Standard Penetration Tests (SPTs) will be performed in accordance with ASTM D-1586. Standard penetration tests will be performed at the following depths: 0.0-1.5 feet; 1.5-3.0 feet; 3.0-4.5 feet; and 5-foot centers thereafter. In cases where soil sampling for environmental analytical analysis is required, 24-inch spoon barrels may be used in the SPT to obtain a sufficient amount of sample for required analysis. A boring log of the soil type, stratification, consistency, and groundwater level will be prepared.

FIGURE A-1



MONITORING WELL CONSTRUCTION DETAIL
(TRAFFIC AREA)
NOT TO SCALE

FIGURE A-2



MONITORING WELL CONSTRUCTION DETAIL
(NON TRAFFIC AREA)
NOT TO SCALE

SAMPLING

Soil samples of the subsurface materials will be collected every five feet or change in formation throughout the borehole in accordance with ASTM Method D-1586. Each soil sample will be screened in the field using an HNu photoionizer, organic vapor detector or similar type direct readout instrument to identify the presence of petroleum product within the soils. This field screening will provide a preliminary indication of the vertical and horizontal extent of contamination in order to select the optimum locations of other monitoring wells during the drilling program. Based on the field screening, two-inch or four-inch diameter monitoring wells will be installed at the locations where the most significant accumulation of fuel is encountered.

WELL INSTALLATION

After completion of soil sampling and drilling to the specified depth, two-inch and/or four-inch (as required by the EIC) inside-diameter, flush-threaded Schedule 40 PVC (Schedule 80 in traffic areas) monitoring wells with slotted screens and well casings will be installed in the borehole. A 5- to 15-foot section of 0.01-inch slotted PVC well screen shall be used in each well. A sand pack will be placed around the slotted well screen extending to 2 feet above the top of the screen. A bentonite seal (minimum thickness of 1 foot) will be placed on top of the sand pack. Finally, a grout mixture of three to four percent bentonite powder (by dry weight) and seven gallons of water per 94 pound bag of cement, thoroughly mixed, will be placed in the borehole to insure a proper seal.

WELL DEVELOPMENT

All wells will be developed not less than 24 hours following their installation to remove fine ground materials that may have entered the well during construction. Wells shall be developed until water runs relatively clear of fine-grained materials. Note that the water in some wells does not clear with continued development. Typical limits placed on well development may include any one of the following:

- Clarity of water based on visual determination.
- A maximum time period (typically one hour for shallow wells, well depth of 10 to 30 feet).
- A maximum well volume (typically three to five well volumes).

- Stability of specific conductance and temperature measurements (typically less than 10 percent change between three successive measurements).
- Clarity based on turbidity measurements (typically less than 50 NTU).

In addition, a volume equal to any water added during drilling will be removed above and beyond the requirement specified above.

Figure A-3 presents the Field Well Development Log used to document development data. This will be accomplished by either bailing or continuous, low-yield pumping. Equipment used for well installation that may have come in contact with potentially contaminated material will be decontaminated with a high pressure steam wash followed by a potable water rinse. It is assumed that all fluid generated from well development and equipment decontamination can be disposed of on the ground at each respective well site, unless otherwise specified.

The soil removed from the borehole will be piled beneath the drill rig while drilling. The drill equipment and tools will be cleaned prior to drilling each well using a portable decontamination system supplied by the contractor. Washwater at the sites will not be contained, unless otherwise directed by the Government, and may seep into the ground locally.

Supplies and equipment will be transported to the lay-down area designated on the station by the Government. Any office space, trailers, etc., required for drilling, subsequent sampling and shipping shall be arranged and provided by the contractor.

WELLHEAD COMPLETION

A four-inch diameter security pipe with a hinged locking cap will be installed over the well casing top and will be embedded approximately 2.5 feet into the grout.

There are two acceptable methods of completing the wellheads.

In traffic areas (and non-traffic areas where required), a "flush" mount type cover shall be built into a concrete pad as shown in Figure A-1. If the well is installed through a paved or concrete surface, the annular space between the casing and the borehole shall be grouted to a depth of at least 2.5 feet and finished with a concrete collar. If the well is not installed through

FIELD WELL DEVELOPMENT RECORD

Baker

Baker Environmental, Inc.

PROJECT: ______________________________

CTO NO.: ____________________ WELL NO.: ______________

DATE: ____________________

GEOLOGIST/ENGINEER: ______________________________

TIME START	
TIME FINISH	
INITIAL WATER LEVEL (FT)	
TOTAL WELL DEPTH (TD)	
WELL DIAMETER (INCHES)	
CALCULATED WELL VOLUME	
BOREHOLE DIAMETER (INCHES)	
BOREHOLE VOLUME	
AMOUNT OF WATER ADDED DURING DRILLING	
DEVELOPMENT METHOD	
PUMP TYPE	
TOTAL TIME (A)	
AVERAGE FLOW (GPM)(B)	
TOTAL ESTIMATED WITHDRAWAL AxB =	
HNU/OVA READING	

DEVELOPMENT DATA

TIME	CUMULATIVE VOLUME (gallons)	pH	TEMP (°C)	SPEC. COND. (μmhos/cm)	TEMP (°C)	COLOR AND TURBIDITY

OBSERVATIONS/NOTES

a concrete or paved medium and still finished as a high traffic area well, a concrete apron measuring 5-foot by 5-foot by 0.5 foot will be constructed around each well. This apron/collar will be constructed of 3,000 psi ready-mixed concrete. The concrete will be crowned to provide and to meet the finished grade of surrounding pavement as required. The concrete pads can be constructed within five days after all of the wells have been installed.

In non-traffic areas the acceptable method of finishing a wellhead is shown in Figure A-2. Each well will be marked with three, Schedule 40 steel pipes, three-inch I.D., embedded in a minimum of 2.5-foot of 3,000 psi concrete. (The concrete used to secure the three pipes will be poured at the same time and be an integral part of the 5-foot by 5-foot by 0.5-foot concrete apron described above.) The security pipes will extend a minimum of 2.5 feet and maximum of 4.0 feet above the ground surface. The steel marker pipes will be filled with concrete and painted day-glo yellow or an equivalent. Attachment C presents Sample Field Test Boring Records and Field Well Construction Record Forms.

In all finishing methods, the well covers will be properly labeled by metal stamping on the exterior of the security pipe locking cap and by labeling vertically on the exterior of the security pipe or manhole cover, as appropriate. The labeling shall consist of the letters UGW (UST Groundwater) (to describe the medium and the reason for the well) and a number specific to each well.

A sign reading "NOT FOR POTABLE USE OR DISPOSAL" shall be firmly attached to each well.

* The contractor or project team may supplement these requirements, but may not modify or delete them, in total or in part, without prior approval of the EIC.

If any part of the above specifications is in conflict with the regulations set forth by the State, the State regulations take precedent.

ATTACHMENT B

ALTERNATE WELL CASING MATERIAL JUSTIFICATION

ATTACHMENT B

ALTERNATE WELL CASING MATERIAL JUSTIFICATION

The following is EPA's minimum seven point information requirements to justify the use of PVC as an alternate casing material for groundwater monitoring wells. If requested by EPA (USEPA Region IV), justification of the use of PVC should be developed by addressing each of the following items.

1. The Data Quality Objectives (DQOs) for the samples to be collected from wells with PVC casing as per EPA/540/G-87/003, "Data Quality Objectives for Remedial Response Activities."

2. The anticipated compounds and their concentration ranges.

3. The anticipated residence time of the sample in the well and the aquifer's productivity.

4. The reasons for not using other casing materials.

5. Literature on the adsorption characteristics of the compounds and elements of interest for the type of PVC to be used.

6. Whether the wall thickness of the PVC casing would require a larger annular space when compared to other well construction materials.

7. The type of PVC to be used and, if available, the manufacturers specifications, and an assurance that the PVC to be used does not leach, mask, react or otherwise interfere with the contaminants being monitored within the limits of the DQOs.

ATTACHMENT C

FIELD TEST BORING RECORD AND FIELD WELL CONSTRUCTION RECORD FORMS

FIELD WELL CONSTRUCTION LOG

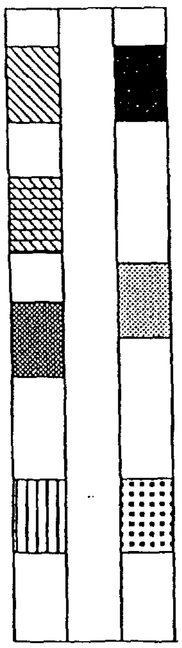
Baker Environmental, Inc

PROJECT: ______________________ DATE: __________
CTO NO.: ______________________ BORING NO.: __________
COORDINATES: EAST: __________ NORTH: __________
ELEVATION: SURFACE: __________ TOP OF STEEL CASING: __________

Pay Items			
Item	Quantity	Unit	Remarks

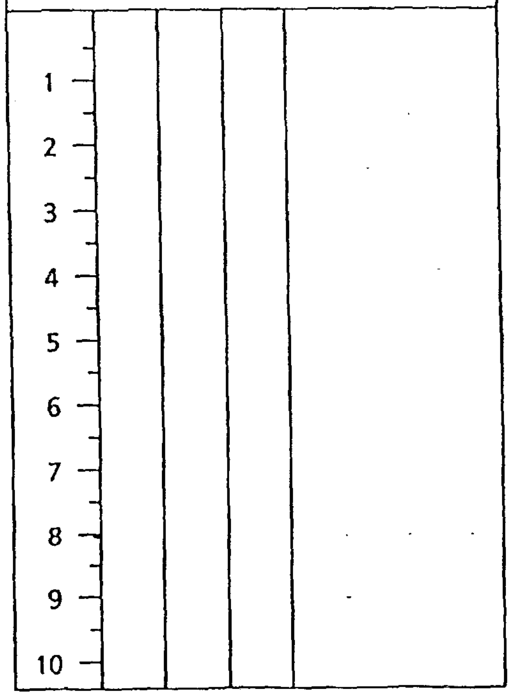
WELL INFORMATION	DIAM. (INCHES)	TYPE	TOP DEPTH (FT.)	BOTTOM DEPTH (FT.)
Well Casing				
Well Screen				

Backfill Key

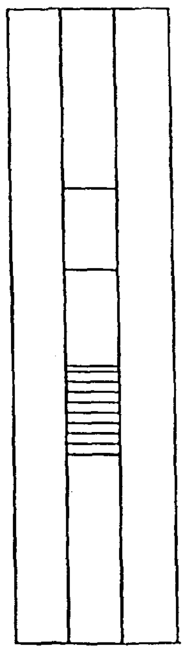


Cement (#1)
Cement/ Bentonite (#0)
Bentonite (#2)
Drill Cuttings (#3)
Rubber Packer (#4)
Sand (#5)
Gravel (#6)

Well Installation Detail



Well Key



Solid Casing (#7)
Slotted Screen (#8)

DRILLING CO.: ______________________ BAKER REP.: ______________________
DRILLER: ______________________ BORING NO.: __________ SHEET ___ OF ___

Baker

Baker Environmental, Inc

FIELD WELL CONSTRUCTION LOG

PROJECT: ______________________

S.O. NO.: ______________ BORING NO.: ______________

Well Installation Detail

1
2
3
4
5
6
7
8
9
0
1
2
3
4
5
6
7
8
9
0

Backfill Key

Cement (#1)

Cement/ Bentonite (#0)

Bentonite (#2)

Drill Cuttings (#3)

Rubber Packer (#4)

Sand (#5)

Gravel (#6)

Well Key

Solid Casing (#7)

Slotted Screen (#8)

DRILLING CO.: ______________ BAKER REP.: ______________

DRILLER: ______________ BORING NO.: ______________ SHEET __ OF __

Baker

Baker Environmental, Inc

TEST BORING AND WELL CONSTRUCTION RECORI

PROJECT: ______
S.O. NO.: ______ BORING NO.: ______
COORDINATES: EAST: ______ NORTH: ______
ELEVATION: SURFACE: ______ TOP OF PVC CASING: ______

RIG:					DATE	PROGRESS (FT)	WEATHER	WATER DEPTH (FT)	TIME
	SPLIT SPOON	CASING	AUGERS	CORE BARREL					
SIZE (DIAM.)									
LENGTH									
TYPE									
HAMMER WT.									
FALL									
STICK UP									

REMARKS:

SAMPLE TYPE

S = Split Spoon A = Auger
T = Shelby Tube W = Wash
R = Air Rotary C = Core
D = Denison P = Piston
N = No Sample

WELL INFORMATION	DIAM	TYPE	TOP DEPTH (FT)	BOTTOM DEPTH (FT)

Depth (Ft.)	Sample Type and No.	Samp. Rec. Ft. & %	SPT or RQD	Lab. Class. or Pen. Rate	PID (ppm)	Visual Description	Well Installation Detail	Elevatior Ft. MSL
1								
2								
3								
4								
5								
6								
7								
8								
9								
10						Match to Sheet 2		

DRILLING CO.: ______ BAKER REP.: ______
DRILLER: ______ BORING NO.: ______ SHEET 1 OF 2

Baker

Baker Environmental, Inc.

TEST BORING AND WELL CONSTRUCTION RECORD

PROJECT: ______________________

S.O. NO.: ______________ BORING NO.: ______________

SAMPLE TYPE	DEFINITIONS
S = Split Spoon; A = Auger; T = Shelby Tube; W = Wash; R = Air Rotary; C = Core; D = Denison; P = Piston; N = No Sample	**SPT** = Standard Penetration Test (ASTM D-1586) (Blows/0.5') **RQD** = Rock Quality Designation (%) **Lab. Class.** = USCS (ASTM D-2487) or AASHTO (ASTM D-3282) **Lab. Moist.** = Moisture Content (ASTM D-2216) Dry Weight Basis

Depth (Ft.)	Sample Type and No.	Samp. Rec. (Ft. & %)	SPT or RQD	Lab. Class. or Pen. Rate	PID (ppm)	Visual Description	Well Installation Detail	Elevation Ft. MSL
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								

DRILLING CO.: ______________ BAKER REP.: ______________

DRILLER: ______________ BORING NO.: ______________ SHEET 2 OF 2

APPENDIX D

Groundwater Sample Acquisition

GROUNDWATER SAMPLE ACQUISITION
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- 5.3 Evacuation of Static Water (Purging)
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  - 5.4.4 Field Filtration
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GROUNDWATER SAMPLE ACQUISITION

1.0 PURPOSE

The purpose of this guideline is to provide general reference information on the sampling of groundwater wells. The methods and equipment described are for the collection of water samples from the saturated zone of the subsurface.

2.0 SCOPE

This guideline provides information on proper sampling equipment and techniques for groundwater sampling. Review of the information contained herein will facilitate planning of the field sampling effort by describing standard sampling techniques. The techniques described should be followed whenever applicable, noting that site-specific conditions or project-specific plans may require adjustments in methods.

3.0 DEFINITIONS

None.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the specific groundwater sampling techniques and equipment to be used, and documenting these in the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team

Leader and the Project Manager. The sampling personnel are responsible for the proper acquisition of groundwater samples.

5.0 PROCEDURES

To be useful and accurate, a groundwater sample must be representative of the particular zone being sampled. The physical, chemical, and bacteriological integrity of the sample must be maintained from the time of sampling to the time of testing in order to minimize any changes in water quality parameters.

The groundwater sampling program should be developed with reference to ASTM D4448-85A, Standard Guide for Sampling Groundwater Monitoring Wells (Attachment A). This reference is not intended as a monitoring plan or procedure for a specific application, but rather is a review of methods. Specific methods shall be stated in the Sampling and Analysis Plan (SAP).

Methods for withdrawing samples from completed wells include the use of pumps, compressed air, bailers, and various types of samplers. The primary considerations in obtaining a representative sample of the groundwater are to avoid collection of stagnant (standing) water in the well and to avoid physical or chemical alteration of the water due to sampling techniques. In a non-pumping well, there will be little or no vertical mixing of water in the well pipe or casing, and stratification will occur. The well water in the screened section will mix with the groundwater due to normal flow patterns, but the well water above the screened section will remain largely isolated and become stagnant. To safeguard against collecting non-representative stagnant water in a sample, the following approach should be followed during sample withdrawal:

1. All monitoring wells shall be pumped or bailed prior to withdrawing a sample. Evacuation of three to five volumes is recommended for a representative sample.

2. Wells that can be pumped or bailed to dryness with the sampling equipment being used, shall be evacuated and allowed to recover prior to sample withdrawal. If the recovery rate is fairly rapid and time allows, evacuation of at least three well volumes of water is preferred; otherwise, a sample will be taken when enough water is available to fill the sample containers.

Stratification of contaminants may exist in the aquifer formation. This is from concentration gradients due to dispersion and diffusion processes in a homogeneous layer, and from separation of flow streams by physical division (for example, around clay leases) or by contrasts in permeability (for example, between a layer of silty, fine sand and a layer of medium sand).

Pumping rates and volumes for non-production wells during sampling development should be moderate; pumping rates for production wells should be maintained at the rate normal for that well. Excessive pumping can dilute or increase the contaminant concentrations in the recovered sample compared to what is representative of the integrated water column at that point, thus result in the collection of a non-representative sample. Water produced during purging shall be collected, stored or treated and discharged as allowed. Disposition of purge water is usually site specific and must be addressed in the Sampling and Analysis Plan.

5.1 Sampling, Monitoring, and Evacuation Equipment

Sample containers shall conform with EPA regulations for the appropriate contaminants and to the specific Quality Assurance Project Plan.

The following list is an example of the type of equipment that generally must be on hand when sampling groundwater wells:

1. Sample packaging and shipping equipment - Coolers for sample shipping and cooling, chemical preservatives, and appropriate packing cartons and filler, labels and chain-of-custody documents.

2. Field tools and instrumentation - Thermometer; pH meter; specific conductivity meter; appropriate keys (for locked wells) or bolt-cutter; tape measure; water-level indicator; and, where applicable, flow meter.

3. Pumps

   a. Shallow-well pumps - Centrifugal, pitcher, suction, or peristaltic pumps with droplines, air-lift apparatus (compressor and tubing), as applicable.

   b. Deep-well pumps - Submersible pump and electrical power generating unit, bladder pump with compressed air source, or air-lift apparatus, as applicable.

4. Tubing - Sample tubing such as teflon, polyethylene, polypropylene, or PVC. Tubing type shall be selected based on specific site requirements and must be chemically inert to the groundwater being sampled.

5. Other Sampling Equipment - Bailers, teflon-coated wire, stainless steel single strand wire, and polypropylene monofilament line (not acceptable in EPA Region I) with

tripod-pulley assembly (if necessary). Bailers shall be used to obtain samples for volatile organics from shallow and deep groundwater wells.

6. Pails - Plastic, graduated.

7. Decontamination solutions - Decontamination materials are discussed in SOP F501 and F502.

Ideally, sample withdrawal equipment should be completely inert, economical, easily cleaned, sterilized, and reusable, able to operate at remote sites in the absence of power sources, and capable of delivering variable rates for well flushing and sample collection.

5.2 Calculations of Well Volume

Calculation of gallons/linear feet from a well

$$V = \pi r^2 h$$

Where: V = volume of standing water in well
r = well radius
h = feet of standing water in well

Table 5-1 lists gallons and cubic feet of water per standing foot of water for a variety of well diameter.

TABLE 5-1
WELL VOLUMES

Diameter of Casing or Hole (in.)	Gallons per Foot of Depth	Cubic Feet per Foot of Depth
1	0.041	0.0055
2	0.163	0.0218
4	0.653	0.0873
6	1.469	0.1963
8	2.611	0.3491
10	4.080	0.5454

Notes:
1. Gallons per foot of depth will be multiplied by amount of standing water to obtain well volume quantity.
2. 1 gallon = 3.785 liters
   1 meter = 3.281 feet
   1 gallon water weighs 8.33 pounds = 3.785 kilograms
   1 liter water weighs 1 kilogram = 2.205 pounds
   1 gallon per foot of depth = 12.419 liters per foot of depth
   1 gallon per meter of depth = 12.419 x 10^{-3} cubic meters per meter of depth

To insure that the proper volume of water has been removed from the well prior to sampling, it is first necessary to determine the volume of standing water in the well pipe or casing. The volume can be easily calculated by the following method. Calculations shall be entered in the field logbook:

1. Obtain all available information on well construction (location, casing, screens, etc.).

2. Determine well or casing diameter.

3. Measure and record static water level (depth below ground level or top of casing reference point), using one of the methods described in Section 5.1 of SOP F202.

4. Determine the depth of the well (if not known from past records) to the nearest 0.01-foot by sounding using a clean, decontaminated weighted tape measure.

5. Calculate number of linear feet of static water (total depth or length of well pipe or casing minus the depth to static water level).

6. Calculate the volume of water in the casing:

$$VW = \pi D^2 (TD - DW)$$

$$V_{gal} = VW \times 7.48 \text{ gallons/ft}^3$$

$$V_{purge} = Vgal\,(\#\text{ Well Vol})$$

   Where:

V_W	= Volume of water in well in cubic feet (i.e., one well volume)
π	= pi, 3.14
D	= Well diameter in feet (use (D/12) if D is in inches)
TD	= Total depth of well in feet (below ground surface or top of casing)
DW	= Depth to water in feet (below ground surface or top of casing)
V_{gal}	= Volume of water in well in gallons
V_{purge}	= Volume of water to be purged from well in gallons
# Well Vol.	= Number of well volumes of water to be purged from the well (typically three to five)

7. Determine the minimum number of gallons to be evacuated before sampling. (Note: V_{purge} should be rounded to the next highest whole gallon. For example, 7.2 gallons should be rounded to 8 gallons.)

5.3 Evacuation of Static Water (Purging)

The amount of flushing a well should receive prior to sample collection will depend on the intent of the monitoring program and the hydrogeologic conditions. Programs to determine overall quality of water resources may require long pumping periods to obtain a sample that is representative of a large volume of that aquifer. The pumped volume may be specified prior to sampling so that the sample can be a composite of a known volume of the aquifer.

For defining a contaminant plume, a representative sample of only a small volume of the aquifer is required. These circumstances require that the well be pumped enough to remove the stagnant water but not enough to induce significant groundwater flow from a wide area. Generally, three to five well volumes are considered effective for purging a well.

An alternative method of purging a well, and one accepted in EPA Regions I and IV, is to purge a well continuously (usually using a low volume, low flow pump) while monitoring specific conductance, pH, and water temperature until the values stabilize. The well is considered properly purged when the values have stabilized.

The Project Manager shall define the objectives of the groundwater sampling program in the Sampling and Analysis Plan, and provide appropriate criteria and guidance to the sampling personnel on the proper methods and volumes of well purging.

5.3.1 Evacuation Devices

The following discussion is limited to those devices which are commonly used at hazardous waste sites. Note that all of these techniques involve equipment which is portable and readily available.

Bailers - Bailers are the simplest evacuation devices used and have many advantages. They generally consist of a length of pipe with a sealed bottom (bucket-type bailer) or, as is more useful and favored, with a ball check-valve at the bottom. An inert line (e.g., Teflon-coated) is used to lower the bailer and retrieve the sample.

Advantages of bailers include:

- Few limitations on size and materials used for bailers.
- No external power source needed.
- Inexpensive.
- Minimal outgassing of volatile organics while the sample is in the bailer.
- Relatively easy to decontaminate.

Limitations on the use of bailers include the following:

- Potentially excessively time consuming to remove stagnant water using a bailer.
- Transfer of sample may cause aeration.
- Use of bailers is physically demanding, especially in warm temperatures at protection levels above Level D.

Suction Pumps - There are many different types of inexpensive suction pumps including centrifugal, diaphragm, peristaltic, and pitcher pumps. Centrifugal and diaphragm pumps can be used for well evacuation at a fast pumping rate and for sampling at a low pumping rate. The peristaltic pump is a low volume pump (generally not suitable for well purging) that uses rollers to squeeze a flexible tubing, thereby creating suction. This tubing can be dedicated to a well to prevent cross contamination. The pitcher pump is a common farm hand-pump.

These pumps are all portable, inexpensive and readily available. However, because they are based on suction, their use is restricted to areas with water levels within 10 to 25 feet of the ground surface. A significant limitation is that the vacuum created by these pumps will cause significant loss of dissolved gases, including volatile organics. In addition, the complex internal components of these pumps may be difficult to decontaminate.

Gas-Lift Samples - This group of samplers uses gas pressure either in the annulus of the well or in a venturi to force the water up a sampling tube. These pumps are also relatively inexpensive. Gas lift pumps are more suitable for well development than for sampling because the samples may be aerated, leading to pH changes and subsequent trace metal precipitation or loss of volatile organics. An inert gas such as nitrogen is generally used as a gas source.

Submersible Pumps - Submersible pumps take in water and push the sample up a sample tube to the surface. The power sources for these samplers may be compressed air or electricity. The operation principles vary and the displacement of the sample can be by an inflatable bladder, sliding piston, gas bubble, or impeller. Pumps are available for two-inch diameter wells and larger. These pumps can lift water from considerable depths (several hundred feet).

Limitations of this class of pumps include:

- Potentially low delivery rates.
- Many models of these pumps are expensive.
- Compressed gas or electric power is needed.
- Sediment in water may cause clogging of the valves or eroding the impellers with some of these pumps.
- Decontamination of internal components is difficult and time-consuming.

5.4 <u>Sampling</u>

The sampling approach consisting of the following, should be developed as part of the Sampling and Analysis Plan prior to the field work:

1. Background and objectives of sampling.

2. Brief description of area and waste characterization.

3. Identification of sampling locations, with map or sketch, and applicable well construction data (well size, depth, screened interval, reference elevation).

4. Sampling equipment to be used.

5. Intended number, sequence volumes, and types of samples. If the relative degrees of contamination between wells is unknown or insignificant, a sampling sequence which facilitates sampling logistics may be followed. Where some wells are known or strongly suspected of being highly contaminated, these should be sampled last to reduce the risk of cross-contamination between wells as a result of the sampling procedures.

6. Sample preservation requirements.

7. Schedule.

8. List of team members.

9. Other information, such as the necessity for a warrant or permission of entry, requirement for split samples, access problems, location of keys, etc.

5.4.1 Sampling Methods

The collection of a groundwater sample includes the following steps:

1. First open the well cap and use volatile organic detection equipment (HNu or OVA) on the escaping gases at the well head to determine the need for respiratory protection. This task is usually performed by the Field Team Leader, Health and Safety Officer, or other designee.

2. When proper respiratory protection has been donned, sound the well for total depth and water level (decontaminated equipment) and record these data in the field logbook. Calculate the fluid volume in the well according to Section 5.2 of this SOP.

3. Lower purging equipment or intake into the well to a short distance below the water level and begin water removal. Collect the purged water and dispose of it in an acceptable manner (e.g., DOT-approved 55-gallon drum).

4. Measure the rate of discharge frequently. A bucket and stopwatch are most commonly used; other techniques include using pipe trajectory methods, weir boxes or flow meters.

5. Observe peristaltic pump intake for degassing "bubbles" and all pump discharge lines. If bubbles are abundant and the intake is fully submerged, this pump is not suitable for collecting samples for volatile organics. The preferred method for collecting volatile organic samples and the accepted method by EPA Regions I through IV is with a bailer.

6. Purge a minimum of three to five well volumes before sampling. In low permeability strata (i.e., if the well is pumped to dryness), one volume will suffice. Allow the well to recharge as necessary, but preferably to 70 percent of the static water level, and then sample.

7. Record measurements of specific conductance, temperature, and pH during purging to ensure the groundwater stabilizes. Generally, these measurements are made after three, four, and five well volumes.

8. If sampling using a pump, lower the pump intake to midscreen or the middle of the open section in uncased wells and collect the sample. If sampling with a bailer, lower the bailer to the sampling level before filling (this requires use of other than a "bucket-type" bailer). Purged water should be collected in a designated container and disposed of in an acceptable manner.

9. (For pump and packer assembly only). Lower assembly into well so that packer is positioned just above the screen or open section and inflate. Purge a volume equal to at least twice the screened interval or unscreened open section volume below the packer before sampling. Packers should always be tested in a casing section above ground to determine proper inflation pressures for good sealing.

10. In the event that recovery time of the well is very slow (e.g., 24 hours), sample collection can be delayed until the following day. If the well has been bailed early in

the morning, sufficient water may be standing in the well by the day's end to permit sample collection. If the well is incapable of producing a sufficient volume of sample at any time, take the largest quantity available and record in the logbook.

11. Add preservative if required (see SOP F301). Label, tag, and number the sample bottle(s).

12. Purgeable organics vials (40 ml) should be completely filled to prevent volatilization and extreme caution should be exercised when filling a vial to avoid turbulence which could also produce volatilization. The sample should be carefully poured down the side of the vial to minimize turbulence. As a rule, it is best to gently pour the last few drops into the vial so that surface tension holds the water in a "convex meniscus." The cap is then applied and some overflow is lost, but air space in the bottle is eliminated. After capping, turn the bottle over and tap it to check for bubbles; if any are present, repeat the procedure.

13. Replace the well cap. Make sure the well is readily identifiable as the source of the samples.

14. Pack the samples for shipping (see SOP F301). Attach custody seals to the shipping container. Make sure that Chain-of-Custody forms and Sample Analysis Request forms are properly filled out and enclosed or attached (see SOP F302).

15. Decontaminate all equipment.

5.4.2 Sample Containers

For most samples and analytical parameters, either glass or plastic containers are satisfactory. SOP F301 describes the required sampling containers for various analytes at various concentrations. Container requirements shall follow those given in NEESA 20.2-047B.

5.4.3 Preservation of Samples and Sample Volume Requirements

Sample preservation techniques and volume requirements depend on the type and concentration of the contaminant and on the type of analysis to be performed. SOP F301 describes the sample preservation and volume requirements for most of the chemicals that will be encountered during hazardous waste site investigations. Sample volume and preservation requirements shall follow those given in NEESA 20.2-047B.

5.4.4 Field Filtration

In general, preparation and preservation of water samples involve some form of filtration. All filtration must occur in the field immediately upon collection. The recommended method is through the use of a disposable in-line filtration module (0.45 micron filter) utilizing the pressure provided by the upstream pumping device for its operation.

In Region I, all inorganics are to be collected and preserved in the filtered form, including metals. In Region II, metals samples are to be collected and preserved unfiltered. In Regions III and IV, samples collected for metals analysis are also to be unfiltered. However, if metals analysis of monitoring wells is required, then both an unfiltered and filtered sample are to be collected, regardless of regulatory requirements. Filtration and preservation are to occur immediately in the field with the sample aliquot passing through a 0.45 micron filter. Samples for organic analyses shall never be filtered. Filters must be prerinsed with organic-free, deionized water.

5.4.5 Handling and Transporting Samples

After collection, samples should be handled as little as possible. It is preferable to use self-contained "chemical" ice (e.g., "blue ice") to reduce the risk of contamination. If water ice is used, it should be double-bagged and steps taken to ensure that the melted ice does not cause sample containers to be submerged, and thus possibly become cross-contaminated. All sample containers should be enclosed in plastic bags or cans to prevent cross-contamination. Samples should be secured in the ice chest to prevent movement of sample containers and possible breakage. Sample packing and transportation requirements are described in SOP F301.

5.4.6 Sample Holding Times

Holding times (i.e., allowed time between sample collection and analysis) for routine samples are given in NEESA 20.2-047B.

6.0 QUALITY ASSURANCE RECORDS

Quality assurance records will be maintained for each sample that is collected. The following information will be recorded in the Field Logbook:

- Sample identification (site name, location, project no.; sample name/number and location; sample type and matrix; time and date; sampler's identity).
- Sample source and source description.
- Field observations and measurements (appearance; volatile screening; field chemistry; sampling method; volume of water purged prior to sampling; number of well volumes purged).
- Sample disposition (preservatives added; lab sent to; date and time).
- Additional remarks, as appropriate.

Proper chain-of-custody procedures play a crucial role in data gathering. SOP F302 describes the requirements for correctly completing a chain-of-custody form. Chain-of-custody forms (and sample analysis request forms) are considered quality assurance records.

7.0 REFERENCES

American Society of Testing and Materials. 1987. Standard Guide for Sampling Groundwater Monitoring Wells. Method D4448-85A, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

U. S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA, Environmental Services Division, Athens, Georgia.

APPENDIX E

Surface Water and Sediment Sample Acquisition

APPENDIX F

Land Survey

1.0 PROCEDURES

This is not the section on Decon for Drill Rigs & Monitoring Well Materials

Sampling and monitoring equipment decontamination procedures are described below.

1.1 Sampling Equipment Decontamination Procedures

Equipment and materials utilized during this investigation that will require decontamination includes:

- Field measurement and sampling equipment: water level meters, bailers, compositing bottles, hand corers, hydropunch tool, etc.

The following decontamination procedures are taken from USEPA IV Standard Operating Procedures (1991).

1.1.1 Cleaning Procedures for Teflon® or Glass Field Sampling Equipment used for the Collection of Samples for Trace Organic Compounds and/or Metals Analyses

1. Equipment will be washed thoroughly with laboratory detergent and hot water using a brush to remove any particulate matter or surface film.

2. The equipment will be rinsed thoroughly with hot tap water.

3. Rinse equipment with at least a 10 percent nitric acid solution.

4. Rinse equipment thoroughly with deionized water.

6. Rinse equipment twice with solvent and allow to air dry for at least 24 hours.

7. Wrap equipment in one layer of aluminum foil. Roll edges of foil into a "tab" to allow for easy removal. Seal the foil wrapped equipment in plastic and date.

8. Rinse the Teflon® or glass sampling equipment thoroughly with tap water in the field as soon as possible after use.

When this sampling equipment is used to collect samples that contain oil, grease, or other hard to remove materials, it may be necessary to rinse the equipment several times with pesticide-grade acetone or hexane to remove the materials before proceeding with Step 1. In extreme cases, it may be necessary to steam clean the field equipment before proceeding with Step 1. If the field equipment cannot be cleaned utilizing these procedures, it should be discarded.

Small and awkward equipment such as vacuum bottle inserts and well bailers may be soaked in the nitric acid solution instead of being rinsed with it. Fresh nitric acid solution should be prepared for each cleaning session.

1.1.2 Cleaning Procedures for Stainless Steel or Metal Sampling Equipment used for the Collection of Samples for Trace Organic Compounds and/or Metals Analyses

1. Wash equipment thoroughly with laboratory detergent and hot water using a brush to remove any particulate matter or surface film.

2. Rinse equipment thoroughly with hot tap water.

3. Rinse equipment thoroughly with deionized water.

4. Rinse equipment twice with solvent and allow to air dry for at least 24 hours.

5. Wrap equipment in one layer of aluminum foil. Roll edges of foil into a "tab" to allow for easy removal. Seal the foil wrapped equipment in plastic and date.

6. Rinse the stainless steel or metal sampling equipment thoroughly with tap water in the field as soon as possible after use.

When this sampling equipment is used to collect samples that contain oil, grease, or other hard to remove materials, it may be necessary to rinse the equipment several times with pesticide-grade acetone or hexane to remove the materials before proceeding with Step 1. In extreme cases, when equipment is painted, badly rusted, or coated with materials that are difficult to remove, it may be necessary to steam clean, wire brush, or sandblast equipment before proceeding with Step 1. Any metal sampling equipment that cannot be cleaned using these procedures should be discarded.

1.1.3 Reusable Glass Composite Sample Containers

1. Wash containers thoroughly with hot tap water and laboratory detergent, using a bottle brush to remove particulate matter and surface film.

2. Rinse containers thoroughly with hot tap water.

3. Rinse containers with at least 10 percent nitric acid.

4. Rinse containers thoroughly with tap water.

5. Rinse containers thoroughly with deionized water.

6. Rinse twice with solvent and allow to air dry for at least 24 hours.

7. Cap with aluminum foil or Teflon® film.

8. After using, rinse with tap water in the field, seal with aluminum foil to keep the interior of the container wet, and return to the laboratory.

When these containers are used to collect samples that contain oil, grease, or other hard to remove materials, it may be necessary to rinse the container several times with pesticide-grade acetone before proceeding with Step 1. If these materials cannot be removed with acetone, the container should be discarded. Glass reusable composite containers used to collect samples at pesticide, herbicide, or other chemical manufacturing facilities that produce toxic or noxious compounds shall be properly disposed of (preferably at the facility) at the conclusion of sampling activities and shall not be returned for cleaning. Also, glass composite containers used to collect in-process wastewater samples at industrial facilities shall be discarded after sampling. Any bottles that have a visible film, scale, or discoloration remaining after this cleaning procedure shall also be discarded.

1.1.4 Plastic Reusable Composite Sample Containers

1. Proceed with the cleaning procedures as outlined in Appendix H but omit the solvent rinse.

Plastic reusable sample containers used to collect samples from facilities that produce toxic or noxious compounds or are used to collect in-process waste stream samples at industrial facilities will be properly disposed (preferably at the facility) of at the conclusion of the sampling activities and will not be returned for cleaning. Any plastic composite sample containers that have a visible film, scale, or other discoloration remaining after this cleaning procedure will be discarded.

1.1.5 Well Sounders or Tapes Used to Measure Ground Water Levels

1. Wash with laboratory detergent and tap water.
2. Rinse with tap water.
3. Rinse with deionized water.
4. Allow to air dry overnight.
5. Wrap equipment in aluminum foil (with tab for easy removal), seal in plastic, and date.

1.1.6 Submersible Pumps and Hoses Used to Purge Ground Water Wells

1. Using a brush, scrub the exterior of the contaminated hose and pump with soapy water.
2. Rinse the soap from the outside of pump and hose with tap water.
3. Rinse the tap water residue from the outside of pump and hose with deionized water.
4. Equipment should be placed in a polyethylene bag or wrapped with polyethylene film to prevent contamination during storage or transit.

APPENDIX G

On-Site Water Quality Testing

Appendix H

Water Level, Water-Product Level Measurements, and Well Depth Measurements

1.0 PROCEDURES

The following briefly discuss the procedures for measuring water levels, product levels, and well depth. For all of the procedures discussed, it is assumed that the measurement will be taken from the top of the PVC or stainless steel casing, and that horizontal and vertical control is available for each well through a site survey, such that measurements may be converted to elevations above mean sea level (msl) or some other consistent datum.

1.1 Water Level Measurement

Water levels in groundwater monitoring wells shall be measured from the top of the protective steel casing, unless otherwise specified in the project plans, using an electronic water level measuring device (water level indicator). Water levels are measured by lowering the probe into the well until the device indicates that water has been encountered, usually with either a constant buzz, or a light, or both. The location of the electric cord/tape against the measuring point on the top of the PVC or stainless steel casing is marked for surveys. The water level is recorded to the nearest foot (rounding down) using the graduated markings on the water level indicator cord. The water level then is measured off the cord/tape to the nearest 0.01 foot using an engineers scale. The measurements are combined (feet plus hundredths of a foot) to yield a measurement of the depth to water below the top of the PVC or stainless steel casing. This measurement, when subtracted from the measuring point elevation, yields the water level elevation.

Groundwater levels shall always be measured to the nearest 0.01 foot. However, reporting of water level elevations depends on the accuracy of the vertical control (typically either 0.1 or 0.01 foot).

1.2 Groundwater-Product Level Measurements

The procedure for groundwater product level measurement is nearly identical to that for water level measurements. The only differences are the use of an interface probe that detects both product and water, and the indication signal given by the measurement device. Typically, encountering product in a monitoring well is indicated by a constant sound. When water is encountered, the signal becomes an alternating on/off beeping sound. This allows for the collection of measurements for both the top of the product layer in a well and the water/product interface.

The apparent water table elevation below the product level will be determined by subtracting the "depth to water" from the measuring point elevation. The corrected water table elevation will then be calculated using the following equation:

$$WTE_c = WTE_a + (\text{Free Product Thickness x } 0.80)$$

Where:

WTE_c	=	Corrected water table elevation
WTE_a	=	Apparent water table elevation
0.80	=	Average value for the density of petroleum hydrocarbons. Site-specific data will be used where available.

1.3 Well Depth Measurements

Well depths typically are measured using a weighted measuring tape. The tape is lowered down the well until resistance is no longer felt, indicating that the weight has touched the bottom of the well. The weight should be moved in an up and down motion a few times so that obstructions, if present, may be bypassed. The slack in the tape then is collected until the tape is taut. The well depth measurement is read directly off of the measuring tape, at the top of the PVC or stainless steel casing, to the nearest 0.01-foot and recorded in the Field Logbook.

1.4 Decontamination of Measuring Devices

Water level indicators, interface probes and weighted measuring tapes that come in contact with groundwater must be decontaminated using the following steps after use in each well:

- Rinse with potable water
- Rinse with deionized water
- Rinse with
- Rinse with deionized water

Portions of the water level indicators or other similar equipment that do not come into contact with groundwater, but may encounter incidental contact during use, need only undergo potable water and deionized water rinses.

APPENDIX I

Photoionization Detector (PID)

APPENDIX J

Bacharach Combustible Gas/Oxygen Meter and Personal Gas Monitor Carbon Monoxide Meter

APPENDIX K

Decontamination of Sampling and Monitoring Equipment

APPENDIX L

Decontamination of Drilling Rigs and Monitoring Well Materials

APPENDIX M

Sample Preservation and Handling

ATTACHMENT A

REQUIRED CONTAINERS, PRESERVATIVE TECHNIQUES AND HOLDING TIMES

Parameter	EPA Document SW-846 (3rd Ed.)				Contract Laboratory Protocol			
	Container	Preservative	Holding Time(1)		Container	Preservative	Holding Time(2)	
			Soil	Water			Soil	Water
Volatiles by GC/MS and GC	Water - 40 mL glass vial with Teflon-lined septa Soil-glass with Teflon-lined septa	Cool to 4°C	14 days	14 days	Water - 40 mL glass vial with Teflon-lined septa Soil-glass with Teflon-lined septa	Conc. HCl Cool to 4°C	10 days	10 days
PCB/Pesticides	G, Teflon-lined lid	Cool to 4°C	Extract within 7 days, analyze 40 days	Extract within 7 days, analyze 40 days	G, Teflon-lined lid	Cool to 4°C	Extract within 10 days, analyze 40 days	Extract within 5 days, analyze 40 days
Semivolatiles/ CSM(3)	G, Teflon-lined lid	Cool to 4°C	Extract within 7 days, analyze 40 days	Extract within 7 days, analyze 40 days	G, Teflon-lined lid	Cool to 4°C	Extract within 10 days, analyze 40 days	Extract within 5 days, analyze 40 days
Metals(4)	P, G	HNO_3 to pH <2	6 months	6 months	P, G	HNO_3 to pH <2	180 days	180 days
Mercury	P, G	HNO_3 to pH <2	28 days	28 days	P, G	HNO_3 to pH <2	26 days	26 days

(1) From date of sample collection in field.
(2) From date of sample receipt at laboratory.
(3) CSM - Chemical Surety Materials
(4) Dissolved metals (liquid) must be field filtered prior to preservation.
Note: Check with laboratory for specific volume requirements.

APPENDIX N

Chain-of-Custody

APPENDIX O

Field Logbook